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Background of the Proposal for Revision of the Constitution

By H. S. ROGERS

Chairman, Committee on Revision of the Constitution and By-Laws

Our Society has one of the finest traditions for cooperation and freedom from politics or ulterior motives of special blocs. Throughout its history it has focused its objectives upon the welfare and advancement of engineering education. Its operations within Committees, Divisions, Sections, and Branches, have been vitalized by enthusiastic interest in, and loyalty to, our educational and professional fields. Its history has been a continuous record of growth and development.

Inaugurated under a very brief constitution with simple structure, it has amended that constitution and revised that structure from time to time to meet the needs of service to engineering education. Originally there was one classification of membership, that of the individual. The institutional membership was created in 1913 for the specific purpose of conveying the influence of the Society back to faculty members on the campus. Later on, in 1918, Sections were authorized for the purpose of giving regional forums for the study and advancement of engineering education. Shortly thereafter, in 1922, By-Laws were adopted for the organization of Branches and Divisions.

The first Division established was that of Deans and Administrative Officers. During the first twenty years of its existence, the problems of principal concern to this Division were those of administration within the engineering schools and the Division served as a forum and a clearing house mainly for discussion and consideration of these common internal problems.

There were few, if any, common problems of relationships with other organizations, or governmental agencies or bodies. The problems of World War I were met by the officers and general committees of the Society. World War II, however, with selective service and deferments, with A.S.T.P. and N.C.T.P., with contracts between the schools and O.S.R.D. and other agencies, with many problems of legislation and public policy, presented new conditions and new difficulties to the administrators of the schools. The need for reorientation and perhaps reorganization of the Administrative Division thereupon became urgent.

At the 1942 convention in New York City there was serious discussion among some administrators of the organization of a special group to meet some of these problems. It was, however, decided that the wiser plan would be to reorganize and stimulate the Administrative Division. This reorganization and stimulation of the Division proceeded progressively throughout

1942–43 and 1943–44. The results, however, did not satisfy all of the needs which some felt for unity and coordination, and at the Cincinnati convention a definite proposal was made to organize a special group of administrators similar to the Engineering College Research Association.

This action prompted the Council of the Society to appoint a Committee on Revision of Constitution and By-Laws to study ways and means of effecting a measure of autonomy and establishing unity in the approach to and solution of problems confronting engineering administrators.

In the light of this background, the Committee has carried forward the work which was reported in the last issue of the JOURNAL.

Please!

Please do not send cash through the mails. Make your remittance for dues by check or money order. The Society cannot be responsible for remittances in cash unless they come by registered mail. This warning seems necessary due to the increasing number of members sending cash through the mails.

The Status of Engineering During the Middle Ages and the Renaissance

By JASPER O. DRAFFIN

Professor of Theoretical and Applied Mechanics, University of Illinois

Ancient Engineering

General Conditions

Though many books have been written on the political and social aspects of the period called the Middle Ages, between 500 A.D. and 1500 A.D., there has been but little written on the subject of the engineering of that time. This paper is an effort to help remedy that lack by outlining the place occupied by the constructive arts in mediaeval civilization. Obviously the treatment must be suggestive rather than exhaustive.

It seems to be commonly assumed that, in common with other cultures, the knowledge and practice of engineering, which had reached a fairly high state with the Romans, almost ceased to exist. Now if we consider the matter at all we are likely to be confronted with two questions: (1) Why did the Middle Ages cause or allow the engineering knowledge to decline suddenly and become lost or forgotten? (2) Why did this knowledge gradually reappear a thousand years later?

My rather dogmatic answer to these questions is that while engineering knowledge did not advance during the Middle Ages it did not become wholly lost but rather went into a state of hibernation, or less active use than formerly, and that as the need arose sufficient knowledge was there to satisfy the need. The view that I hold on this matter is expressed by various writers who believe that the essential achievements of the Greeks and Romans have become a part of our civilization either directly or indirectly. One writer refers to a change in the course of civilization rather than a cessation of it.[1] Another writer expresses the same idea, that of the persistence of knowledge, when he says, ". . . if we build Houses of Parliament or churches, we build something which perhaps our mediaeval forefathers would not have built but something, too, which we should not have built as we have built it if they had not built it before us."[2]

It is my intention to discuss the status of engineering in the Middle Ages by briefly delineating and interpreting the characteristics and achievements of each of the principal periods, somewhat arbitrarily selected, and by showing that the status of the engineering of any given period coincided with the economic and social life of that period. Only by looking at the engineering of any period against the total background of that period can it have any significance, for the reason that engineering construction follows closely behind social mores. One well-known

writer expresses this view with respect to political and economic affairs by saying, ". . . the current views of right and wrong . . . give the basis of all economic institutions and the atmosphere in which they worked. . . ."[3] It must also always be kept in mind that many of the structures which were built have vanished without records of them and that the structures of which we know are perhaps only a small part of those actually built.

The basis of engineering is, (1) an organized, permanent and stable society, (2) a flourishing industry, and (3) adequate transportation; these are the three keys to engineering needs and development.

I regard it as axiomatic that there must be an established and orderly government if engineering is to function and produce structures and machines. Only under such conditions will it be possible to promote the need for, the desire for, and the financial means to build engineering works. A state of law and order and a large degree of permanence must exist if the engineering arts are to be practiced, even though the civilization may be a brutal, cruel and intolerant one. A wild, barbaric population on the march, migrating, advancing and retreating is not concerned with the construction of relatively permanent structures. To produce engineering constructions there must also be a fairly large population engaged in other than agricultural pursuits, *i.e.*, industry, for it has been abundantly demonstrated that agriculture, being practically self-contained at the subsistence level, does not promote engineering in any country which lives at the subsistence level. Finally there must be a means of distributing the products of agriculture and industry, *i.e.*, transportation.

As a preliminary to a discussion of the Middle Ages and in order that we may more clearly visualize the ebb and flow of engineering achievement I shall indicate briefly: (1) what constitutes engineering and certain stages in its progress, (2) what it was that the Romans inherited, and (3) what the Romans achieved.

Looking first at the items included in early engineering construction we find three types: civil engineering, architecture, and the industrial arts. Civil engineering is concerned with roads, bridges, harbors, lighthouses, aqueducts, drainage, irrigation systems and surveying, which latter is necessary to all of them. Architecture comprises the planning and construction of temples, cathedrals, castles, tombs, monuments, pyramids and palaces, including the sculpture in and on them. The industrial arts include the technical crafts such as the mining of ore and extraction of the metals, making of bricks, pottery and other ceramic wares, building of vehicles for traveling on land and water, painting, carpentry, masonry, and the domestic arts such as baking, brewing, spinning, and weaving.

Naturally the work in each of these three groups has always been done by more or less skilled artisans but the first two, civil engineering and architecture, must have had at the head of the project one or more people who conceived the scheme, prepared the plans, and supervised the execution of the work; any other arrangement for the genesis and consummation of an elaborate piece of work is inconceivable. This view is aptly expressed by the statement,

"It is a mistake to think there were no architects in the great periods of the past.

. . . Great art cannot be produced by a committee, nor could anything so complex as the Parthenon or Salisbury Cathedral have leapt from the ground at the behest of a handful of rustic masons."[4]

There have been really only two phases of engineering, pre-power engineering and power engineering, though of course each of these phases may be divided into sub-phases according to various criteria. One such division is as follows: The *pre-power era:* (a) the post and lintel structure developed by the Egyptians, Greeks and Romans; (b) the arch, used extensively by the Romans, 200 B.C. to 1500 A.D. The *power era:* (a) the early casting and machining of metal cylinders which led to stationary engines, 1500–1800; and (b) the application of power to transportation, 1800– . Only the pre-power era will be discussed in detail.

The Roman Inheritance

Egyptian.—Apparently the Egyptions were the first to develop the post and lintel type of construction, about 3000 B.C., and use it in their stone buildings, which were fashioned with the aid of copper tools.[5] Their instruments were simple but they did a good job of surveying.

Their structures, pyramids, temples and sculptures, were primitive and crude in design but they were well executed; while they were sometimes grostesque according to our sense of artistry, some of them had a degree of delicacy which was in accord with the Egyption conception of beauty. The builders and workmen were ingenious, resourceful and accustomed to long-term planning as is evidenced by the fact that the stone for the pyramids was quarried 500 miles up the Nile,[6] floated down in barges and hoisted into place, probably by means of ramps of earth which were later removed. The quarrying, transportation and erection of long slender shafts of stone is a delicate task, even with our modern equipment, but they did it well.[7] It was a land with an orderly government, though a cruel and despotic one, as well as one with considerable commerce, especially in the interior parts. Along the Nile and across the Red Sea, boats carried trade to various parts of the kingdom. Thus order and commerce went hand in hand with engineering excellence and development.

Babylonian.—Following the Egyptians, the next contributors were the inhabitants of the Tigris-Euphrates Valley and the Fertile Crescent. The Babylonians and Chaldeans contributed astronomy, irrigation, and brick-and-tile-making; the Assyrians and others in the Black Sea region added their bit with discoveries of iron, steel and bronze. Their art corresponded with the taste of the peoples but according to our aesthetic sense their structures were rude and undeveloped. Their buildings were massive but refinement of form was not one of their characteristics. Since stone was scarce in this region they did little work with this material.

Greek.—The advent of the Greeks in the constructional field was manifested through excellent workmanship, refinement of design, form and proportions. They had better means than the Egyptions for handling stone because they had tackle and other mechanical appliances, operated by hand of course. Their structures were marked by symmetry, beauty, and grace and corresponded somewhat with their speculative philosophy. There is evidence[8] that the Greeks understood something

of the proportioning of structural members to resist loads but how complete this information was we do not know. Nevertheless, in spite of many contributions which they made, the Greeks did not add permanently any essentially new element to the *engineering* side of construction.

Roman Achievements

Organization of the Empire.—Between 500 B.C. and 500 A.D. the Roman Empire was the backbone of Europe. It included a great diversified group of people from the cultured Greek to the Barbarian German, wild Briton and savage Slav. Physically the Empire was two thousand miles north and south and three thousand miles east and west, a body of land which included the Mediterranean Sea in its embrace. It should be noted that the pathway of advance and civilization was westward and northward from western Asia and Egypt to Greece, Rome and other countries bordering on the Mediterranean Sea. This progression took place somewhat in the order of, and was no doubt conditioned by, the recession of the ice blocks which covered northern Europe and which made the north a region of barbarians and inhabitants of the stone age while the peoples of southern Europe were relatively highly civilized and living in the bronze and iron ages.

As the Romans came into power and supplanted the Greeks politically, they inherited the accumulated knowledge of the past. They borrowed the arts from the Greeks and those borrowed arts served them well even though in general they were not able to execute their works as well as the Greeks had done. For a thousand years the Roman Empire was devoted to building and colonizing an industrial nation and, since it was unified politically, convenient access to all parts was needed. This need caused the central government to build adequate transportation facilities, such as roads, bridges, and ships. Consequently engineering and architectural construction throve and grew in this trading, industrial country. It is true that Roman edicts were enforced and reinforced with military might but still they were enforced and law and order prevailed.

Roman Engineering.—There was nothing approaching mechanical engineering in Roman or other ancient times: There was no demand for machinery, nothing for machinery to do; there were no tools for the cutting and exact measuring necessary in the making of machinery and in the working of metals; there was no adequate power to operate machinery if it had existed.

Magnificent palaces were built for the rulers and places of entertainment for the populace, harbors were improved and lighthouses were built. Water was brought into Rome and other cities and in some cases measures were taken to improve its quality, such, for instance, as removing the sediment. Their knowledge of hydraulics was imperfect; they knew some of the principles of hydrostatics but, judged by their methods of measuring the quantity of flowing water, they knew relatively little about hydrodynamics.[9] Their surveying instruments were crude and, whether from the instruments or from the users, there were many inequalities in the lines and grades of the aqueducts. The magnificant structures which they created were evolved by slow methods of construction; for instance, they fractured the rock in tunnelling by heating it and throwing water against it. They

used enormous quantities of lead in their plumbing and much iron in their war instruments; the lead and iron ores were mined and the metals extracted in Britain and Spain.

The Arch.—Up to and including the Greeks, practically all construction was of the post and lintel type. The arch had been used by various peoples but it was not common. The Romans, having apparently borrowed it from their northern neighbors the Etruscans, used it extensively and thereby made their most important contribution to engineering. In general they used short spans and wide piers for their arches, including the nearly thirty miles of arches built for the support of aqueducts. These arches were not as everlasting as popular fancy sometimes makes them; some were built and rebuilt many times. However the arches supporting the aqueducts of Segovia, Spain, built 19 B.C.; Claudia, Rome, built 38 A.D.; and Pont du Gard, France, built 109 A.D., merit our admiration today as among some of the most majestic of the ancient structures. In spite of the prevailing short spans in common use, some of the Romans were daring in their use of the arch principle, as is evidenced in the construction of the dome of the Pantheon, 143 feet in diameter, placed on walls reputed to have been 20 feet thick. Part of the success of this enormous dome must be credited to the use of puzzelana cement, invented by the Romans.

Thus Rome, which had borrowed from Egypt, Greece and other older civilizations of Asia, Africa and Europe, passed on to posterity the great public works which it had constructed and also passed on the traditions of such building. The introduction of the arch on a large scale is the one really essential structural element introduced in engineering between about 200–300 B.C. and 1800 A.D. when iron was introduced as a new building material. Only one structural element added but what an addition! Between the massive bulk of the Pantheon or the solidity of the Coliseum and the refinements, the delicate balance and exquisite workmanship, of, say, Cologne or Salisbury Cathedral there is a great gap, a gap bridged by all the known art of man applied to the arch. That new element, the arch, had wonderful potentialities for, like the lily bulb lying in the ground through a long winter, it finally flowered in the beautiful, airy, graceful unfolding of the Gothic Cathedrals, the summit of the constructors art of the pre-power age.

Mediaeval Engineering

Character of Civilization.—If we are to evaluate correctly the influences which have played upon society and thus upon engineering, it is not only necessary to examine the achievements of early engineering, which has been done, but to consider briefly some of the political history of mediaeval Europe.

First it is essential to understand that mediaeval civilization was a thing by itself. It was neither a replica of ancient civilization nor a model of modern civilization. It had distinctive features of its own and the engineering construction of that period fits into the civilization which existed. Adams maintains convincingly that the period which included the fall of Rome was one of the important periods of history.[10] It was a reorientation of society preparatory to a more advanced and better civilization, a time when the uncivilized or semi-civilized peoples of Europe were being welded into a unit with the Roman part of Europe and

these various parts were being assimilated into each other.[11]

When we consider the factors which affect the engineering of the Middle Ages we find there are many conflicting currents, periods overlapping each other, and at any one time the trends in one place may have been the opposite of those in another place; yet in the total picture there were three events which contributed to the decline of construction during the Dark Ages and three events which had a tendency to keep construction alive.

The events causing a cessation of construction were the Teutonic invasions, the Norse invasions, and the rise of feudalism. The three events tending to perpetuate construction were the continuation of the Byzantine Empire, the rise and spread of Islam, and the growth of Christianity, the latter being manifested through the institutions of the papacy and monasticism and through the Crusades. The first three events tended to blot out any need for engineering while the other three, though they did not increase knowledge greatly, kept knowledge alive and gave it continuity, strength and virility, all of which helped to preserve engineering.

Just as bench marks and traverse lines are needed for references in a survey, so some of the approximate dates in the Middle Ages are needed. For the purpose of this paper I have, somewhat arbitrarily, placed the major movements and the dates at which they occurred about as follows, all being of course A.D.

Construction Retarded	
Teutonic Invasions	375–750
Charlemagne's State	768–853
Norse Invasions	800–900
Otto-Frederick Kingdom and Papacy	936–1250
Feudalism	825–1400

Construction Maintained	
Byzantine Empire	330–1453
Rise of Islam	622–750
Crusades	1095–1300
Renaissance	1500–1760

Teutonic Invasions (375–750).—While Rome was still mistress of her Empire, the Roman colonies in Europe were bounded on the east and north, roughly, by the Danube and Rhine Rivers. The people immediately east and north of these rivers, the Goths, Vandals, and other Teutonic tribes such as the Saxons, Lombards and Franks, were themselves pressed from the east and north by the wild, migrating tribes such as the Huns from north and central Asia and the Slavs from the hinterland of Russia. These savage migrants, some of them just emerging from the bronze age, pressed upon the Roman neighbors, the Teutons, and caused them to spill over into the Roman dominions. At first this was with Roman consent and the Teutons entered as slaves, as farmers and as soldiers, all of whom settled into the community life and were slowly absorbed into the Roman pattern of society with a fair degree of completeness so that they became a constituent part of the Roman empire.[12] As time passed there was a more rapid influx of these barbarian tribes and, beginning in about 375 A.D. and lasting for two or three hundred years, they overran the country and swamped the former population. One scholarly statesman phrases the conditions thus,

". . . they [the Franks] were pressed, on the northeast by new populations; their expeditions were not merely forays for pillage, they were matters of necessity; they were disturbed in their settlements and went elsewhere to seek their fortune. . . . the entire Slavonic race which pressed upon the Germanic, and from the

sixth to the ninth century compelled it to advance toward the west." [13]

Besides this invasion from without, there were economic disturbances and pillage from within which resulted in some of the land being flooded by the cutting of the aqueducts. The uncultivated land was soon rendered uninhabitable by lack of drainage and by the malaria which followed.[14] All these things, and many others, contributed to internal decay and as a consequence the Roman civilization gradually crumbled until in 476 A.D. the western ramparts of the Roman Empire gave way and Rome "weathered away" and "fell."

The invaders were agricultural in their inclinations and were not given to industrial or mercantile pursuits to the same extent that the Romans were and the nation by about 600 A.D. had become largely agricultural.[15] There was a certain amount of overland commerce through the foreign (Eastern) merchants who came in to trade and also some commerce through Italy and the Mediterranean with the Byzantines as well as coastwise and river traffic on the north and east. But on the whole, outside trade languished and overland commerce largely ceased. With the change from urban to rural life the cities were abandoned and buildings vanished; even the memory of some of the past life seems to have been lost.

Engineering Lies Dormant (375–750).—The conditions regarding engineering in the Western Roman Empire during the period of upheaval, instability and political collapse is well expressed by various writers. Gest says, ". . . the breaking up of the unified system of government, and, later, the introduction of the feudal system were not favorable to the construction of new works, or even to the maintenance of the old." [16] In a similar vein Adams, who is a staunch believer in the importance and survival of the Greek and Roman contributions, describes the feelings of the invading Germans, the Franks, as those of wonder and bewilderment. They did not understand the culture which they saw and therefore did not desire it. They had little use for roads and bridges which were therefore not maintained and consequently communication grew less; commerce in both goods and ideas dwindled.[17]

In spite of the depressing facts and appraisals just enumerated, construction was not entirely at a standstill for it is recorded that Benedict Biscop built a stone church at Monckwearmouth on the river Wear, England, in 674 A.D. He could not find masons or glassmakers in England and so sent to France for them.[18] Evidently some artizans still remained in France. Records indicate [19] that four churches were built in Italy in the 6th century and five in the 7th century, some of these being due to the Byzantine influence which at this time was strong in Italy. Engineering was somnolent, perhaps in a coma, but it was not dead.

Charlemagne's State (768–853).—The dark picture just painted does not depict the entire situation during the Dark Ages. Following the fall of Rome and the withdrawal or submergence of the Roman people and the Roman culture in Gaul, the untutored Teutonic tribes (the Franks) took control under Clovis, who embraced Christianity in 496. From a loose tribal government the Frankish States (the Merovingian and the Carolingian kingdoms) began to take shape and grow until finally a semblance of control, cruel and brutal as it was, developed in

western Europe and lasted, with varying fortunes, for three or four centuries.

The Frankish State reached its greatest height under the dominant Charlemagne who began to rule in 768 and until he died in 814 continued to form and govern one of the great empires of Europe. He appears to have held strong religious views on some things and this fact probably influenced church building. It was a period of intermittent warfare between tribes and groups of tribes but all in all it is probably fair to say that, "By the 8th century Western Europe had measurably recovered from the degradation and barbarism entailed by the decay of Roman civilization and German invasions. Roman, ecclesiastical, and Germanic institutions had fused into a new civilization." [20]

Revival of Engineering (768–853).—Since the Frankish State was predominantly rural there was but little construction of a civil character. For military purposes Charlemagne constructed a bridge over the Rhine at Mayence at about the close of the 8th century and projected a canal to connect the upper reaches of the Danube and Rhine Rivers.[21] The first lighthouse at the mouth of the Gironde River, predecessor of the Cordouan, was built in 805.[22] Charlemagne and his successors also gave considerable attention to roads and bridges; in some places he put them in charge of monasteries. One writer says,

> "That some consideration was given to bridges during the Dark Ages is proved by instructions addressed by Charlemagne to his Missi-Dominicis, asking them to cooperate in each city with the Bishop and Count in order to assure the maintenance of public roads and bridges. Also, an order of Louis le Dononnaire in 825 gave extension of time for the repair of all bridges and one in 830 ordered the construction of twelve bridges over the Seine." [23]

Charlemagne gave an impetus to architecture through his fairly elaborate church at Aix-la-Chappele, the capital, which was built around 800 A.D. This church, which was also the tomb of Charlemagne, was rather pretentious and was evidently copied from St. Vitale in Ravenna, Italy. It seems clear that the church was not built by local artizans but by imported workmen. An historian of architecture considers that, "With the plan and the materials, it would seem that Charlemagne must also have imported the architects and workmen to realize his scheme, for there could have been no local craftsmen capable of rearing such a building." [24] This same view is held by the noted architect Cram who says Charlemagne was "the first great builder for five centuries," but he goes on to say that Charlemagne did not inaugurate new styles but merely stimulated into activity former builders and traditions. Cram names three sources from which Charlemagne's workmen might have been obtained: (1) the builders from Lombardy in the north of Italy, where the earlier Lombards from the north had migrated as an entire people in 568 A.D., (2) from Ravenna, Italy, and finally, (3) from the ". . . Comacini [who] were the lineal successors of the old Roman guilds . . . and had preserved somewhat of their organization and their methods and traditions." [25]

These Comacini were without doubt the principal organization which kept alive the spirit of building during these troubled times. The importance of their work is indicated by the follow-

ing extract, ". . . distance and obstacles were nothing to them: they traveled to England . . . to Germany . . . to France. The Popes . . . gave them privileges. Indeed the builders may be considered an army of artizans working in . . . all places where the missionaries . . . had prepared the ground for them." [26] Meanwhile building still went on in Italy as well as in the north countries according to the conclusions of some writers for one of them says, "The seventh and eighth centuries were times of great devotion to the church and consequently a great church building era." [27]

Mining and metallurgy were also beginning to be revived because iron making, probably by means of the wolf furnace or "Stücköfen," was thriving in parts of Germany where a "celebrated" iron was being produced in 780 A.D.[28]

Taking into consideration all of the items mentioned, roads and bridges, churches and metal working, it is evident that during the reign of Charlemagne, under the stimulus of strong government, engineering was being resuscitated from its coma.

Norse Invasions (800–900).—In spite of the political advances made during Charlemagne's reign, his death brought divisions, internal wars, and the separation of all territory into small parts so that by the middle of the ninth century the great Frankish State had disintegrated. One factor in this decline was the invasion, 800–900, of the Norsemen who emigrated from Scandinavia into Britain, Germany and Gaul. These people created a new disturbance for they were wild, untutored, sea-faring rovers, pirates and traders with a bronze age civilization.[29] Probably because of over-population in Scandinavia or of oppression from some powerful ruler there, these marauders, instead of leaving with their plunder, settled their families in the lands which they invaded and pillaged; here they remained to form more or less permanent settlements.

Engineering Creates Foundations (800–900).—At first the Norse advanced engineering but little. There is a record of ten churches built during the 9th century,[30] including the predecessor of the present Cathedral of Cologne which was begun in 814 and completed in 873 A.D.[31] Most of these churches were in Italy. However the Norsemen made little or no contribution to the advancement of architectural construction because they merely copied from earlier examples; one writer concludes that they exerted no influence on architecture until around 1000 A.D.[32] Indirectly they stimulated the construction of bridges; they came up the rivers into the interior, particularly into Normandy, and in about 861 Charles the Bald built a fortified bridge, "pont portifie," across the Seine to repel the invaders.[33]

It would be a mistake, however, to place too much emphasis on the lack of actual construction. The Norsemen were a vigorous race, traders and sea-faring men, rather than agriculturists. They had traits which infused new life into western Europe, a life of vigor and of commercial enterprise; Thompson, who has studied this phase extensively, says, "Economic history has shown that the Norse invasions were the most powerful stimulus to mediaeval trade before the Crusades." [34] Their crude barbarism, tamed by Christianity, mingled with the elements remaining from the Roman Empire produced a stalwart race. They helped to open trade routes between the East and the West including an overland route

from the Baltic Sea to the Black Sea and, for a time, one up the Danube to the West.

Thus they competed in trade and commerce with the Moslem pirates who by this time had gained control of the western Mediterranean areas and who were active in sea-borne commerce. Ship building seems to have flourished more than most industries of the time, with Venice, under Moslem and Byzantine influence, probably leading all other cities. Consequently this period of comparative inactivity in actual engineering construction was important for in it was laid a groundwork for future engineering needs and desires.

The Otto-Frederick Kingdom and the Papacy (936–1250).—Otto I, aided by Pope John XII, who crowned him Emperor, followed the example of Charlemagne and founded a kingdom which embraced Germany and Rome, a sort of Rome-Berlin Axis. The Holy Roman Empire, as it is sometimes called, existed for over three hundred years, a period during which important economic and social developments took place.

While life was still predominantly agricultural, population increased, order was established, fairs and trade routes increased, cities grew in numbers and size. Thompson says, ". . . the number of corporate cities increased ten-fold between 1100 and 1300 and . . . their population sometimes doubled and trebled." [35] Not all was peaceful for naturally there were many conflicts between the various rulers of the Holy Roman Empire and between them and the popes, all of which created confusion and disorder. In the midst of all the disorder and intrigue there came a great religious revival in the 10th century.

It is necessary now to look more closely at the effect of the religious movements. During the period of the political decline of the Roman Empire, the three great Christian fathers, Saint Ambrose, Saint Jerome and Saint Augustine, administered, wrote and preached so effectively that by the time the Roman Empire had collapsed, Christianity had been preached and accepted, at least nominally, throughout the southern part of the Roman Empire but it had not yet become an integral part of the life of northern Europe. However during the next five hundred years, the Dark Ages, Christianity became fixed and permanent throughout most of Europe, even though its precepts were not always obeyed.

One of the institutions of Christianity which affected society was monasticism, which was founded by Saint Benedict in about 500 A.D. and greatly encouraged by Pope Gregory I (the "Great"). After Christianity had been accepted by large numbers of people there was a rush to the monasteries, a rush for security and safety, after each period of war or distress. Western monasticism (which differed markedly from that ancient institution in Oriental countries) was one of the powerful agencies in the development of civilization in the Middle Ages.[38]

The monasteries indirectly promoted engineering by promoting the dignity of labor, the preservation of learning and the care of travellers. In some places the monks operated model farms, improved the breeding of plants and animals, cleared forests, drained swamps and marshes, repaired roads and built bridges. One of the oldest stone bridges in England was built at

Croyland, probably by monks around 943 A.D.[37]

The other institution of Christianity which wielded a tremendous influence was the papacy, which became important in about 600 A.D. under Gregory I. Since the popes possessed or assumed both spiritual and political authority they constituted an element of profound importance, unfortunately not always for the best, in the life of Europe for the next six or eight centuries. Added to the other Christian movements were the Crusades, which will be discussed later.

Engineering Leaps Forward (936–1250).—The revival of religion together with the Cluniac and allied reformations [38] promoted the building of churches everywhere, and especially the majestic basilica of Cluny which was begun in 1083.[39] Each community vied with its neighbor in the construction of cathedrals. While these magnificent structures cannot by any stretch of the imagination be attributed to the policies of the Holy Roman Empire, it is a fact that during the first two hundred years of its existence there was a resurgence of engineering construction which manifested itself in the numerous Romanesque cathedrals, in bridges and in iron furnaces. Following the two centuries of Romanesque architecture came the thirteenth century with the wonderful Gothic cathedrals. It was a time of unprecedented progress. A famous German historian of engineering said in 1939, "Wherever we look, we already find examples of high engineering art in the Middle Ages. . . ." [40] In a book characterized by Nicholas Murray Butler as ". . . a classic in the literature of the field which it covers," the eminent W. B. Parsons pays a high tribute to the engineering excellence of Gothic structures. He says,

"The Gothic design is, therefore, a beautiful balancing of large static forces and is the greatest contribution of science to construction found in the thousand years that separated the fall of Rome from the beginning of the Renaissance. From the standpoint of scientific construction Gothic architecture had but one rival in prior time, the Dome of the Pantheon. . . ." [41]

Bridges too received careful attention during this period. In England in the early part of the 12th century Queen Mathilda ordered two bridges built over the River Lea and endowed them for maintenance.[42] The best known bridge of that time, at least among English speaking people, was the London Bridge. A bridge probably existed at that site in early times for reference is made to London Bridge in an account of the execution of a witch between 963 and 984 A.D. Then in 1196 Peter, chaplain of St. Mary's Colechurch, built the famous stone bridge, a feat that required 33 years to accomplish.[43]

Tyrrell in his extensive work lists many stone arch bridges built during this period in various countries of which the following is a partial enumeration: In France: Saint Esprit near Nimes, 1265–1309; Guillotiers, Lyons, 1265; Pont Valentre, Cahors, 1280; Pont Albi, 1035; Pont Carcassonne, 1180. In Italy: Ponte Vecchio, Florence, 1177; Admiral, Paterno, 1113. In central Europe: Ratisbon, 1135; Dresden, 1179–1260; Berne, 1204.[44] These bridges varied in length from 150 to 2,600 feet with one to 26 spans. Some bridges were built also in Spain but they are mentioned under other classifications.

It seems clear that the amount of

engineering construction during this period of 300–350 years was increasing rapidly over that of former years.

Feudalism (825–1400).—Most of the period covered by this topic has of course been covered under earlier headings and consequently no new facts regarding the amount of engineering work can be presented. Nevertheless some additional reasons will be shown for the changes which took place, some explanation for the events which occurred. To discuss feudalism, this state of society with its special customs, laws and consequences, would require a whole book but so far as engineering is concerned its essential aspect is that of isolation. The people, with exceptions, "were subject to a master and bound to the land." [45] A region was under a feudal lord and, though he owed allegiance to the king, he had a more or less absolute control over his area. He had his own land, workers who went with the land, castle and soldiers. His entourage was relatively self-contained.

Because feudalism was self-contained and because it was essentially a farming economy and had but little trade with other communities and countries it had relatively little need for engineering, though this fact of isolation helped to preserve industrial knowledge by requiring each manor to maintain its own domestic industries.[46] Besides the castle or manor house there were villages and workshops. The necessary food, clothing, housing, and implements of peace and war were mostly produced on the land and in the workshops. There was of course some trade with the towns and cities which survived and with the regional fairs; iron, salt, sulphur, and pitch, for instance, could not be produced in each manor.[47] Metal working involved the training of smiths and armorers who were highly esteemed. This esteem is shown by the fact [48] that William the Conqueror brought smiths and armorers with him when he came to England in 1066 and that these men were accorded high places in the state because of the importance of their work.

In the cities, between the 11th and 13th centuries, manufacturing was done under the guild system. These guilds were supposed to train a craftsman, to insure goods of high quality and to assure each workman of "a position of self-respect and of independence" with adequate compensation, a condition "such as he had never held before and has failed to achieve since." [49] Though the guilds did provide a reasonable degree of security, in the latter part of the feudal period, for those who were admitted to them, it is doubtful whether the ideal conditions just mentioned ever existed. Many writers claim that poor workmanship and inferior goods from the guilds were very common. Cunningham calls attention to this when he says, "These associations were able to ensure the production of wares of really good quality. They [the guild associations] had so far ceased to fulfill these functions that their own ordinances were brought under control of the justices in 1437." [50]

Many feudal manors were essentially fortified garrisons which involved extensive construction. At first the castles were built of wood, then the lower parts were of stone and the upper parts of wood. Finally about the close of the 11th century and later, "great baronial castles were built with massive walls, deep moats and intricate drawbridges—structures of no mean size and importance in engineering conception." [51] Thus, though the so-

cial economy demanded relatively little engineering, the fact that such construction was done in places indicates that there were workmen capable of doing this type of work whenever it needed to be done. If they could not be found on the manor they were imported from some other place but still they could be found somewhere.

There was little incentive for a feudal lord to construct or maintain large municipal facilities because the cities of western Europe declined in size until such civil works as water supplies were no longer needed as much as formerly. It is estimated that the population of Rome, for instance, fell from a million to a mere 50,000, with some authorities placing it as low as 20,000–30,000; other cities disappeared.

Likewise no feudal baron was interested in promoting elaborate highways from his manor to other manors, for, while it made his traveling easier, it made it easier for his enemy to attack him. Consequently the elaborate road system built by the Romans had no central organization to keep the roads in repair and they went to pieces but the disintegration of the roads was not due solely to the lack of constructive ability.

The boundaries of seigniories were often streams or rivers, a frequent boundary in the early grants in this country, which furnished natural fortifications. Neither side desired a bridge which, in addition to being a financial burden, would make an attack on his domain easier. Some of the bridges which were built had elaborate precautions for defense, as in the Pont Valentre and the Saint Benezet's bridge at Avignon, France, which was 2,000 feet long and had 22 stone arch spans.[52] It seems clear that the small number of bridges which were built, small in total number, was not due to lack of engineering ability. One writer sums up the matter very well when he says,

"The work of the Romans furnished excellent models, and the difficulties of building foundations in most locations was not insurmountable,"

and

"The splendid ecclesiastical monuments erected under the direction of the clergy or of religious communities as the influence spread, proved that the failure to build bridges was not due to the lack of capable architects and skilled workmen." [53]

In concluding our consideration of feudalism and its effect on engineering with its isolating influence, its tendency to divide, we should not overlook the indirect, as well as the direct, influence of Christianity, for it was principally through Christianity that the Roman elements were perpetuated. The Romans were not philosophical, scientific or speculative people; instead they were law-givers, organizers and builders. The peculiar products of the Roman genius were retained in western civilization through Christianity which formed a unifying or cementing force that held together the fragments into which feudalism broke Europe, somewhat as a plastic holds together pieces of broken glass. Thus the isolating effects of feudalism on engineering were partly nullified by Christianity which not only held the fragments together but in addition furnished an incentive, a stimulating purpose, for the construction of cathedrals, in the building of which the greatest engineering of the Middle Ages was performed.

Buttresses of Engineering

Having examined some of the causes which retarded the use and develop-

ment of engineering during the Dark Ages, we shall now look at some of the forces which helped to perpetuate science and engineering and to keep it alive in the period when it was not highly regarded or desired in western Europe.

Byzantine Empire (330–1453 A.D.).—Under this topic we shall epitomize the part Byzantium had in perpetuating the constructive arts and in holding the line against the forces which would dissolve civilization.

The Roman Empire was composed of two rather distinct units, the western part and the eastern part, with centers at Rome and Constantinople respectively. The Empire in the east was more urban than that in the west, having great cities with extensive trade. The marauding invaders, Goths, Vandals and others who had swept in from north of the Black Sea region, had occupied the farming regions of the western part of the Roman Empire but they had not conquered the eastern part which thus formed a barrier to the unrestricted westward advance of the Persians, Arabs, Turks and other Asiatic tribes.

Not only from the military side but also from the economic side the cities were tremendously important. The most influential one was Constantinople which, located as it was at the junction of Europe and Asia, commanded the entrance of the Mediterranean and Black Seas and the trade routes of Egypt, Syria and India. Here on a jutting triangle at the junction of the lower Danube and Upper Euphrates valleys, on the site of ancient Byzantine, which had been a town engaged in the wheat trade since about the time Israel was defeated and carried away by the Assyrians and Romulus was said to have established Rome, Constantine built a city, named after himself and opened in 330 A.D. It was defended on the land side with inner and outer walls and on the water side by the Bosphorus and the Sea of Marmora.

As the western part of the Empire succumbed to decay from within and barbarian onslaughts from without, the eastern part continued to thrive and grow, especially during the period 527–565 A.D. under Justinian. Impelled by his desire to rebuild the fallen western empire, Justinian eliminated the Vandals and conquered North Africa, Italy and the southeastern part of Spain. It was impossible for Justinian to drive the Visigoths out of Spain because of trouble at home; the Huns, Slavs and Avars were pressing the Byzantine Empire hard as is shown by the fact that only twelve years after the death of Justinian, which occurred in 565 A.D., a wave of 100,000 Slavs pushed into the lower Balkans. Yet in spite of occasional breaks, the Eastern Roman or Byzantine Empire stood as a guardian, a bulwark, for the West from the Asiatic hordes for over a thousand years.

Between the 5th and 11th centuries, during the Dark Ages, the Byzantine Empire was the only really active Christian civilization in Europe since, as already indicated, the others were undergoing a metamorphosis. Though Justinian closed the Academy at Athens in 529 and learning, especially scientific learning, did not advance in the Byzantine Empire, there was little retrogression. Here among the Byzantines the past cultural and intellectual treasures of Greece and Persia survived to some extent, "shone as a torch," [54] and served to light the torches of western learning even though there was little

or no addition to the store of knowledge.

The Byzantine Empire contributed to art, especially in the churches. The Greek Catholic church with its impressive and elaborate ritualism encouraged art and doubtless art encouraged ritualism. Thus the invading or migrating Slavs became Catholic through their contact with Byzantine life and culture. In the 8th century came the iconoclastic controversy and other differences which split the church permanently into two branches, the Roman Catholic and the Greek Catholic. Probably this division influenced the types of architecture which later became dominant in each region. All of this ecclesiastical activity is very definitely related to engineering because it kept alive the spirit of progress and was a potent factor in promoting the building of churches which at that time furnished the principal outlet for the practice of the constructive arts.

Byzantine structures were substantial in character and the Byzantines did considerable work on the east coast of Italy where the construction of that period bears a strong impress of their influence. The aqueduct of Bourgas near Contantinople, which was built in 560 A.D., was 720 feet long with two tiers of arches.[55] Another aqueduct was that of Justinian which was rebuilt in about 550 A.D.[56] In this latter aqueduct there is evidence that allowance was made for the effect of earthquakes, which were sometimes violent in that region. In Italy a semi-circular arch bridge was built in the 6th century over the Teverone River.[57]

The most conclusive example of the constructive art of the Byzantines is the magnificent church Santa Sophia in Constantinople. Built in 532–537 A.D., it is a triumph of dome building which has never been repeated. Due to an earthquake the first dome fell about twenty years after it was built and the present dome was then built higher and more magnificent than the first one. A number of other churches were built in Constantinople around the middle of the 10th century. In Ravenna the famous church of St. Vitale was built in 530 A.D. while in Venice the Ducal Palace was built in 814 and St. Mark's Cathedral in 829–1063. Two churches were built at Salonica at the end of the 8th century. All of these structures show the influence of the Byzantine style. It is said that "Even the basic Gothic principle, the stabilizing of a complex vaulted system by means of an equilibrium of opposing thrusts, finds its antecedent . . . in the Byzantine architecture of the second golden age."[58] Certainly the constructive art was not in total eclipse during even the darkest of the Dark Ages.

Rise of Islam (622–750 A.D.).—Other trustees of the scientific knowledge of the Middle Ages were the Arabs. They were a nomadic, pastoral people with a high degree of civilization whose national life centered in Arabia. This desert land was unable to support a large population and therefore the people fought fiercely for the possession of the fertile areas, the oases; they traded with their neighbors, were constantly on the move and had never been subdued by any power.

The contact of the Arabs with western Europe and the consequent dissemination of knowledge came about through their religion. Though they rendered allegiance to Allah, they were not greatly inclined to piety. But in 622 A.D. Mohammed attacked the heathen shrines in Mecca and for this he was driven to Medina. Here he

proclaimed himself the prophet of the one and true god with the result that converts came rapidly. The religion of Mohammed was one of legality and not love. The watchword might well have been, "Obey and be rewarded; Disobey and be punished!" This interpretation of life led to a philosophy of fatalism and predestination and gave rise to or justification for the reckless, fatalistic attitude that life lost fighting for Islam meant an abode in Paradise. It was this philosophy which furnished the zeal that won victories for the wild and restless Moslems.

Mohammedanism was a fighting religion and by 750 A.D. it had overrun Persia, a part of India, Syria, North Africa, and Spain. It was prevented from spreading over the whole of Europe by the Byzantine Empire at Constantinople in the east and by Charles Martel in 732 at Tours in the west. Though in general the Arabs were not a building people, they constructed a number of mosques and bridges and did much shipbuilding. The Cordova bridge in Spain, which contains 16 spans, was built in 916 [59] and the Alcantara bridge at Toledo in 997. The Arabs kept alive the previous knowledge of philosophy and the sciences, including medicine, chemistry, mathematics and physics. Though they added something to the store of knowledge, their ability did not lie in creating it but rather in preserving and transmitting it to others.

The Crusades.—As previously indicated, the passing of the Dark Ages and the beginning of the Age of Revival in the eleventh century was marked by a religious fervor which exhibited itself in various ways. Since the days of Mohammed there had been continued conflict between the Moslems and the Christians with considerable success by the Moslems, especially through the capture and possession of Palestine. In 1095 Pope Urban II asked the Christians of western Europe, some writers claim upon the request of the Byzantine Emperor Alexius Comnenus, to regain the Holy Land and restore it to Christendom. This action of the pope inaugurated the Crusades which raged for two hundred years.

The Crusades proved to be a boomerang for the Byzantine Empire because in 1204 the Crusaders attacked, captured and sacked Constantinople, massacred the Byzantines, took manuscripts and works of art to the west and destroyed vast stores of them. In 1453 Constantinople fell to the Moslems and with this fall came the end of the Byzantine Empire. The capture of Constantinople caused many educated men to flee to western Europe where they helped to spread the Eastern culture and knowledge and to lay the foundations for the Renaissance.

There are various views concerning the effect of the Crusades. One writer belittles their influence on intellectual growth but emphasizes the revival of trade aspect by saying, "The most important effect of the Crusades was the increase in commerce between East and West." [60] Another writer says,

> "They [the Crusades] were a great common movement of all Europe, sharing in alike in motive and spirit and action by all the nations of the West. . . . They are an indication . . . that the days of isolation and separation are passing away." [61]

From the engineering point of view our interest in the Crusades lies in the impetus which they gave to the spread of knowledge, to the stimulation of curiosity, and in the expansion of the

horizon of the participants. The returning Crusaders brought back new and sometimes strange ideas, customs, and goods which aroused wonderment and created desires in the western peoples, who by this time had recovered fairly well from the shock of the various invasions and were therefore ripe for progress.

The restless spirit of the north pushed its way across Europe and into the East into new adventures and new ideas. The Crusades started by overland routes and then gradually changed to sea routes. These sea travels stimulated shipbuilding for traffic on the Mediterranean and in the waters on the west of Europe and brought the Crusaders into contact with a civilization which was better than its own. Whether the dominant engineering activity, the construction of cathedrals, was increased by the Crusades is difficult to prove. The two activities took place simultaneously and undoubtedly influenced each other. Certainly the greatest engineering achievements of the Middle Ages were made during the period of the Crusades.

The Renaissance

The Interim.—From the end of the 13th century to the end of the 15th century there were no notable developments in engineering. The advances made in the preceding centuries were held fast and a number of bridges and a large number of churches, including the Cathedral of Florence with its mighty dome by Brunelleschi, were built. The amount of engineering construction increased but the general character of it did not change materially. That genius Leonardo da Vinci (1452–1519) dabbled in all of the military, constructive and decorative arts of his time but he is best known for his artistic work.

1500–1760.—The engineering of the Renaissance will be discussed only briefly in order to round out the picture. While the Arabs did some scientific work it did not filter into Europe very fast and there was little written progress in the development of scientific theory, as it applied to engineering, until the time of Stevin, about 1600, and of Galileo, about 1630–1640. Then followed rapidly Huygens, Newton and others who laid the theoretical foundations of our knowledge of forces and their actions.

Meanwhile there was a general increase in the construction of communication facilities such as roads, bridges, canals, harbors, docks and lighthouses. The present Cordouan lighthouse at the mouth of the Gironde River in France was begun in 1584,[62] while the first one at Eddystone was begun in 1696 under the direction of the Brethren of the Trinity.[63] The one built by Smeaton in 1756 was perhaps the most noted in the English-speaking world.

However if one is to name a single item which more than any other represents the contribution of the Renaissance to engineering, that item is power. Power, as the term is commonly used, did not come into use to any extent until after the beginning of the Renaissance. One of the earliest books dealing with machinery is that written in 1578 by Besson [64] who shows many mechanical devices, mostly operated by hand though a few are operated by water wheels. Perhaps his most significant machine is a pumping engine, to throw a stream of water at a fire, in which air pressure is apparently used to force the water. Some of the devices are so fantastic as to raise a question as to how many of

the devices pictured were ever built. Somewhat earlier than Besson was that noted book on metallurgy *De Re Metallica* by Agricola (translated by Mr. and Mrs. Herbert Hoover) in which some crude machinery was shown as incidental to the mining and processing of ores.

The development and use of steam power involves the two paths by which engineering has progressed, viz., the scientific and the crafts. The expansive force of steam was known by the Greeks and was utilized in a few cases in the temples. Solomon de Caus described experiments on the expansive power of steam as early as 1616 and the Marquis of Worcester did the same in 1655. Papin demonstrated in 1616 that the condensation of steam would produce an atmospheric force. This demonstration was followed by Savery with his pulsating steam pump or "fire-engine" in 1699 and the Newcomen engine in 1711. Along with these practical attempts to utilize steam, the scientific side of steam was developed by Torricelli in 1643, Pascal in 1647, Guericke in 1654, Boyle in 1660, and Mariotte in 1676. Following the period 1600–1700 the active utilization of steam soon became a reality.

On the crafts side, the making of steam cylinders was an outgrowth of the manufacture of bells and cannon. The casting of bells was done as early as 1150 A.D. in England and reference is made to their manufacture in the early part of the 11th century.[65] The bells were cast of brass and if they were intended to be rung merely for the noise they were left as cast, but if they were to be tuned, they were turned down in a crude lathe or ground.

Cannon were used by the Moors in the defense of Seville in 1247,[66] with their use reported as early as 1118 and by 1339 they were in existence in England.[67] The earliest cast cannon were made of bronze and reference is made to boring these but the first iron ones were not bored from the solid but were made by taking long strips or bars of wrought or puddled iron and binding them together by hoops or bands.[68] These rough tubes were evidently not bored after they were made and it seems that these early cannon were sometimes as dangerous to those who fired them as they were to those against whom they were fired.

The first blast furnace which made liquid pig iron was built in Belgium[69] in 1340 and in 1543 a method was discovered in England of casting iron cannon in a single piece and of boring them.[70]

It is merely a point of view as to whether the power age began with the ability to cast and machine fairly large iron cylinders or whether it began with the first steps toward the utilization of the power of steam. Both were needed before power could be effectively produced. However if we take the Renaissance as about 1500–1760 it is clear that during this period, whether it is in the working of metals or in the use of steam, there was active thinking about power and the means of producing and using it. Earlier than about 1500 there seems to have been no serious thought, except in the most limited way, of using steam as a motive power. The Renaissance therefore marks as clear a transition in engineering as it did in religion, literature and many other phases of thinking.

1760–Present.—Finally came the period beginning about 1760 when engineering burst full-flowered into being with the improvement of the steam

engine by Watt and his competitors and with the improvement of the lathe and metal cutting machinery by Maudsley and others. The time also corresponds with the explosion of political freedom, with injury to many, in the French and American Revolutions. Progress in all fields of endeavor was throwing off its bonds and starting on a gigantic cavalcade.

These scientific and craft improvements combined with the inventive side complete the advance in engineering. From them has flowed the tremendous volume of mechanical and electrical engineering, that utilization of machines and power which has caused this to be called the power age. But it must not be forgotten that the invention of machines for doing work is only an incident, though a most important and necessary one, in the evolution of thought and action which has been going on for the last fifteen hundred years. This invention and use of machines was as inevitable as that day follows night because in general the progress of engineering corresponds with the character of the society of any given period and with the stability of that society. The engineering of the Middle Ages was in accord with the state of society of the times and as society advanced engineering likewise advanced.

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The Measurement and Guidance Project in Engineering Education: A Progress Report

By K. W. VAUGHN, *Director*

Introduction

This is a report of certain activities of the Measurement and Guidance Project in Engineering Education during its second year of operations, the fiscal year ending June 30, 1945. Included in this report are summaries of the extent of testing of engineering freshmen and data pertaining to these students which are collected as an integral part of the research studies conducted by the Project Office. In this report, the general characteristics and educational background of the students tested in the cooperating colleges of engineering are given greatest emphasis. The performance of these students on the *Pre-Engineering Inventory* and the general effectiveness of this test battery are reserved for a later report.

Pre-Engineering Inventory Administrations

One of the major purposes of the present project is to prepare a series of tests which are particularly appropriate for guiding and advising prospective engineering students. The research involved in the development and refinement of the first of these tests, the *Pre-Engineering Inventory*, necessitated the extended cooperation of a number of representative colleges of engineering.[1] The cooperating institutions administer the tests, collect complete data on the educational background and general characteristics of each student, and keep a careful record of the progress of each student as he proceeds through the various courses. These reports are then transmitted to the Project Office for purposes of analysis. From time to time the Project Office summarizes the data collected and issues reports to the cooperating colleges of engineering and the sponsoring agencies.

Cooperating Colleges of Engineering

Formal participation in the Project is limited to a certain number of colleges of engineering selected by the Advisory Council and the Project Office. The selections are made on several bases: the funds available for research purposes and the representativeness of the sample of colleges to be studied—curricular organization, geographical location, source of student body, policies of admission, and other factors being considered. In each of the colleges of engineering so participating, research studies of uniform design are conducted continuously.

The scope of the Project, however,

[1] The general purpose and nature of this series of tests are described in the following reference: K. W. Vaughn, "The Pre-Engineering Inventory," The Journal of Engineering Education, Vol. 34, No. 9, May, 1944, pp. 615–625.

extends beyond this formal participating group of colleges. The Project Office has cooperated with the Army and Navy Training Programs, the recruitment programs of the United States Coast Guard and the United States Merchant Marine Cadet Corps, and testing programs in various other institutions, both educational and industrial. In these "extra" activities, the Project Office has been primarily interested in checking the validity of the Project tests by administering them to groups whose abilities and purposes differ considerably from those of engineering freshmen. By studying these various groups it is hoped that the findings will be of value in better understanding the levels of ability necessary for success in the pre-specialization period of engineering education. With considerable information at hand concerning the tests being used, it is believed that the counselor can better guide the prospective engineering student.

During the first year of study, eleven colleges of engineering cooperated with the Project Office. Of this number, ten colleges administered the *Pre-En-*

TABLE 1

NUMBER OF FRESHMAN STUDENTS TESTED AT COLLEGES OF ENGINEERING FORMALLY PARTICIPATING IN THE PROJECT

College	No. of Testings	No. of Students Tested
Alabama, University of	2	109
*California Institute of Technology	3	100
California, University of (Berkeley)	2	343
California, University of (Los Angeles)	1	55
*Carnegie Institute of Technology	3	353
Case School of Applied Science	4	307
Detroit, University of	2	123
*Iowa, State University of	1	47
Maine, University of	1	51
*Massachusetts Institute of Technology	1	457
Michigan College of Mining and Technology	2	58
*Michigan, University of	3	395
*Newark College of Engineering	3	280
New Mexico College of Agriculture and Mechanic Arts	1	30
*North Carolina State College of Agriculture and Engineering	2	331
*Northwestern University, Technological Institute	2	126
Oklahoma Agricultural and Mechanical College	2	151
Oregon State College	1	115
Polytechnic Institute of Brooklyn	1	100
*Rose Polytechnic Institute	1	33
*Tennessee, University of	2	109
*Texas, University of	3	544
Toronto, University of	2	558
Tulane University of Louisiana	2	63
Wyoming, University of	1	51
Total		4,889

* Institutions cooperating during the first year of the study.

† These numbers are not necessarily indicative of the freshman enrollment for the entire year. In some colleges, one entering class was tested; in others, three classes.

gineering Inventory and supplied data for research purposes. During the past year, the number of participating colleges was increased to twenty-five. The names of these institutions together with the number of students tested during the past year are listed in Table 1.

The present sample of colleges of engineering participating in the study is fairly representative, although some deficiencies still exist. With respect to geographical location, these institutions are located as follows:

United States	24
New England	2
Middle Atlantic	3
South	4
South West	3
Middle West	7
Far West and Pacific Coast	5
Canada	1
Total	25

With respect to financial support, seventeen colleges included in the above tabulation are tax-supported and eight are private or non-tax-supported.

Policies of admission to the twenty-five colleges included in this list vary tremendously. On the one hand are institutions exercising the most rigorous selection policies possible under the prevailing conditions of student supply, while contrasted with these are a number of tax-supported institutions which cannot legally employ selective policies except those consistent with the general state laws operative in their respective states. This wide range of admission policies enables the Project Office to study the progress of students under a number of diverse conditions, thus adding materially to our findings over those possible in a more homogeneous college population.

Although the present sample of colleges of engineering was very carefully balanced in favor of representativeness of engineering education in general, we have not yet been entirely successful in this respect. The most obvious deficiency is the need for several additional *large* colleges of engineering. The present sample is too heavily weighted in favor of the small college. Certain geographical locations need better representation and there is similar need for a better balance between public and private colleges. Plans for the next fiscal year have taken these conditions into account and it is expected that fifteen additional institutions will be invited to participate in the Project. With a larger sample of cooperating colleges, it is hoped that the findings of the Project can become more representative and, consequently, more precise.

Number of Students Tested

Despite the abnormal conditions brought about by the war, the Project has been able to test large numbers of students in the regular Project colleges and in the other institutions which have used the *Pre-Engineering Inventory* for their own purposes. During the first year of the study, approximately 6,000 students were tested, while during the year covered by this report, almost 14,000 freshman engineering students and others were tested by the Project Office.

TABLE 2

SUMMARY OF NUMBER OF STUDENTS TESTED BY THE PROJECT OFFICE JULY 1, 1944 TO JUNE 30, 1945

Institutions	No. of Students Tested
Regular Project Colleges of Engineering	4,889
Other Institutions and Agencies	9,093
Total	13,982

As indicated in Table 2, 13,982 individuals were tested by the Project Office during the past fiscal year. Of this number, approximately 10,000 can be characterized as freshman engineering students; the remainder were individuals interested in related scientific fields or were members of some branch of the Armed Services whose training program was roughly comparable to the pre-specialization program of engineering colleges.

Characteristics of the Students Tested

As a professional school, the college of engineering is greatly concerned with the sources from which its students come, the educational background of the students at the time of admission, and other factors which are likely to affect the quality of product graduating from the college. The Project Office has, therefore, made adequate provision for collecting various types of information about each applicant. This section of the present report summarizes data pertaining to freshman students now enrolled in colleges of engineering.

As an integral part of the examination procedures, each freshman student in the cooperating colleges fills out a *Student Information Blank*. This questionnaire inquires into a number of important aspects of the student's previous experience and background. As an essential part of the administration of the *Pre-Engineering Inventory*, this questionnaire is carefully marked under the supervision of the regular Examiner; consequently, the results from the replies to it can be interpreted with unusual dependence.

The present report summarizes the replies for 3,858 students regularly enrolled in twenty-two of the twenty-five colleges of engineering participating in the Project. These students were tested during the summer and fall of 1944, and constitute what typically would be the September freshman classes in these institutions. Wartime conditions can, of course, scarcely be described as normal with respect to pre-war conditions, but, when students entering in the summer and fall terms are considered together, it is likely that the combined data will approximate the typical wartime conditions now prevailing in student supply. Also, preliminary comparisons of the results for this group of students do not differ noticeably from the results for the more than 10,000 other regularly enrolled engineering freshmen tested during the past two years. It seems safe, therefore, to characterize the following findings as being typical of the wartime engineering freshmen.

General Characteristics and Background

Colleges participating in the Project are classified as Private and Public (tax-supported), and the results for each of these two types of colleges are kept separate for research purposes. In the beginning, this policy was followed on the assumption that systematic differences existed between the two types of institutions. Research findings later bore out this assumption. In this report, therefore, the summaries of data show averages for both types of colleges of engineering as well as their weighted average. Of the 3,858 students considered in this section of the report, 1,131 were enrolled in privately-supported colleges and 2,727 were in attendance at publicly-supported colleges.

Sex.—Although the war years have brought more young women into col-

leges of engineering than formerly, the present findings do not appear to indicate a very strong trend in this direction. As indicated in Table 3, the tax-supported colleges have accepted the largest proportion of women. Two such colleges enrolled 13 per cent women, while three colleges, all private, enrolled no women. In general, it appears that no more than 4 or 5 per cent of the freshman classes in engineering colleges consist of women, even in the period when the demands of war place the highest premium on an engineering education.

TABLE 3

PER CENT OF STUDENTS DISTRIBUTED ACCORDING TO SEX

Type of College	N	Per Cent of Students Enrolled			
		Men		Women	
		Range	Mean	Range	Mean
Public.....	2,727	87– 99	94.7	1–13	5.3
Private.....	1,131	96–100	98.6	0– 4	1.4
All Colleges.	3,858	87–100	96.0	0–13	4.0

Membership in the Armed Forces.—In general, the students included in this sample did not belong to any branch of the Armed Forces. Only regularly-enrolled students were included in the sample. In the total sample, however, 6.9 per cent of the students indicated that they had enlisted in one of the various reserve services and would be called to active service or a training program after they reached a certain age or when new assignments were made by their respective services.

Age.—The accelerated programs brought about by the war have resulted in younger students in attendance at engineering colleges. This is evidenced in Table 4. It is clear, also, that in this respect there is no great difference between the two general types of colleges.

TABLE 4

PER CENT OF STUDENTS DISTRIBUTED ACCORDING TO AGE

Type of College	Age at Last Birthdate					
	15	16	17	18	19	20 or over
Public.....	1.2	9.9	53.5	21.2	5.5	8.7
Private.....	0.2	10.1	48.7	21.9	7.5	11.6
All Colleges.	0.6	10.0	50.4	21.7	6.8	10.5

Place of Birth.—Generally speaking, the freshmen included in the present sample were born in urban areas. Although two tax-supported colleges of engineering obtain approximately 50 per cent of their student body from farms or small villages, most of the colleges in this classification, like the private colleges, draw most heavily on urban areas. Only one of the private colleges enrolled as many as 12 per cent of its student body from the farm and, of the remaining seven colleges in this group, six obtained 5 or less per

TABLE 5

PER CENT OF STUDENTS DISTRIBUTED ACCORDING TO BIRTHPLACE

Type of College	Birthplace			
	Farm	Population of Town or City		
		Under 1,000	1,000–5,000	Over 5,000
Public.....	14.3	7.6	19.9	58.3
Private.....	4.3	3.9	9.5	82.3
All Colleges...	10.8	6.3	16.3	66.6

cent of their students from the farm. Data pertaining to the birthplace of the students in the sample are presented in Table 5.

Character of High Schools Attended

Location of High School.—The typical engineering freshman, as the typical college freshman in general, attends college in the same state in which he attended high school. This is less true of the engineering student enrolled in a private college of engineering, but even in such colleges, more than 70 per cent of the freshmen attended high school in the same state in which the college is located. Data pertaining to the location of high schools from which the students in this sample came are summarized in Table 6.

Size of High School.—Although the average high school in the United States enrolls approximately 250 students, less than one-eighth of this group of engineering freshmen attended high schools of this size or smaller high schools. It is clear that from two-thirds to three-fourths of the students in this group graduated from

TABLE 6

PER CENT OF STUDENTS DISTRIBUTED ACCORDING TO LOCATION OF HIGH SCHOOL ATTENDED

Type of College	Location of High School				
	Same State as College	Contiguous States*	Other States	Outside U.S.	More than one of the preceding
Public...	84.6	7.0	7.2	0.9	0.3
Private..	73.1	13.2	11.1	1.8	0.8
All Colleges	80.5	9.2	8.6	1.2	0.5

* States which are coterminous with the state in which the college is located.

TABLE 7

PER CENT OF STUDENTS DISTRIBUTED ACCORDING TO SIZE OF HIGH SCHOOL ATTENDED

Type of College	Number of Students in High School Attended					
	1–49	50–99	100–249	250–499	500–999	1,000 or more
Public.....	1.0	3.3	13.7	21.0	25.9	35.1
Private....	0.0	0.9	6.0	14.2	27.1	51.8
All Colleges	0.7	2.5	11.0	18.7	26.3	40.8

large high schools, that is, large as compared with the average size of high schools in this country. This fact is, of course, directly related to the fact that approximately two-thirds of these students were born in cities of more than 5,000 population.

Type of High School Attended.—Approximately three-fourths of all students attended a public high school (75.8 per cent). Private secondary schools supplied 11.2 per cent of the students in the private colleges and 6.4 per cent of the students in the public colleges. Church-supported secondary schools supplied 12.7 per cent of the students in private colleges and only 2.1 per cent of the public college students. Only 0.9 per cent of all students attended secondary schools in foreign countries.

In the total sample, 9.8 per cent attended college from one to three semesters before enrolling in the college of engineering.

Educational Background

Type of High School Course.—The two high school curricula which predominately attract the prospective engineering freshman are the college preparatory course and the scientific-technical course. In individual colleges,

TABLE 8

PER CENT OF STUDENTS DISTRIBUTED ACCORDING TO TYPE OF COURSE PURSUED IN HIGH SCHOOL

Type of College	Type of High School Course			
	College Prep.	Scientific-Technical	General	Others
Public	46.7	20.7	28.1	4.5
Private	57.8	28.8	12.9	0.5
All Colleges	50.5	23.5	22.8	3.2

however, the variation in this respect is very great. For example, in one college only 8 per cent of the students pursued the college preparatory course and 6 per cent the scientific-technical course—86 per cent following the general high school course. Contrasted with this was one private college in which 95 per cent of all freshmen had graduated from college preparatory or scientific-technical curricula and only 5 per cent from a general high school course. A summary of data for the entire sample is presented in Table 8.

High School Mathematics Subjects.—Of particular interest is the previous training of freshman engineering students in the field of high school mathematics. Since the engineering curriculum depends heavily on the student's ability to use mathematics as a thinking tool, it is natural that admissions officers place a high premium on the successful completion of the basic high school mathematics subjects. This emphasis is borne out in the proportions of students taking these courses as indicated in Table 9. It is obvious from this table that freshman engineering students, as a group, have

TABLE 9

PER CENT OF STUDENTS DISTRIBUTED ACCORDING TO MATHEMATICS SUBJECTS STUDIED IN HIGH SCHOOL: ALGEBRA, PLANE GEOMETRY, SOLID GEOMETRY, AND ALL OTHER COURSES

Subject / Type of College	Number of Years of Study						
	0	½	1	1½	2	2½	3 or more
Algebra							
Public	0.6	0.9	19.4	22.1	49.6	6.1	1.3
Private	0.0	0.5	4.8	25.9	59.4	8.2	1.2
All Colleges	0.4	0.8	14.1	23.5	53.2	6.8	1.2
Plane Geometry							
Public	3.2	5.4	90.3	1.1			
Private	1.0	4.4	93.6	1.0			
All Colleges	2.4	5.1	91.4	1.1			
Solid Geometry							
Public	48.3	50.8	0.9				
Private	18.1	79.1	2.8				
All Colleges	37.3	61.1	1.6				
All Other Courses (Including Plane Trigonometry)							
Public	26.2	46.7	19.1	4.2	3.9		
Private	17.8	64.1	12.4	4.6	1.1		
All Colleges	23.1	53.0	16.6	4.4	2.9		

TABLE 10

PER CENT OF STUDENTS DISTRIBUTED ACCORDING TO SCIENCE SUBJECTS STUDIED IN HIGH SCHOOL: GENERAL SCIENCE, PHYSICS, AND CHEMISTRY

Subject / Type of College	Number of Years of Study			
	0	½	1	Over 1
General Science				
Public	31.5	2.6	64.7	1.2
Private	41.4	6.5	49.6	2.5
All Colleges	35.1	4.0	59.3	1.7
Physics				
Public	24.6	3.9	69.0	2.5
Private	5.9	4.8	84.9	4.4
All Colleges	17.8	4.2	74.8	3.2
Chemistry				
Public	34.3	2.9	60.1	2.7
Private	13.1	4.0	76.9	6.0
All Colleges	26.6	3.3	66.2	3.9
All Other Courses				
Public	58.9	36.6		4.5
Private	61.5	34.5		4.0
All Colleges	59.9	35.9		4.2

completed more mathematics courses while in high school than the typical student. What is not apparent, of course, is the wide range of variation which is present within the same college as well as the variation between colleges.

This extreme variation is apparent in the data for individual institutions. For example, one private college accepted no students who had not completed at least one and one-half years of high school algebra, whereas in one public college, 43 per cent of the students had completed only one year (or less) of this stubject. Surprising, also, is the fact that more than one-half of all students had completed two full years of high school algebra—the average high school offers only one and one-half years of algebra.

Aside from algebra, only one other mathematics subject, plane geometry, can be characterized as being almost universally taken in high school. This subject was studied by more than nine-tenths of all students in the sample. Solid geometry and all other subjects, generally plane trigonometry, were studied on a one-semester basis by approximately one-half to two-thirds of all students. Although these averages appear to indicate that most students take these subjects, the variation in high school training in the special advanced high school courses is very great.

High School Science Courses.—Three high school science courses, each one year in length, constitute the typical engineering freshman's training in science—general science, physics, and chemistry. Here, as in the case of mathematics, individual colleges vary considerably in their requirements. Consider the following tabulation which reveals this extreme variation.

Science Subject	Range of Per Cent of Students not taking the Subject
General Science	14–64
Physics	0–61
Chemistry	1–70

This tabulation indicates that in at least one college only 1 per cent of the students had not completed high school chemistry whereas in at least one other college 70 per cent of the students had not completed this subject in high school. Table 10 summarizes the data for the entire sample.

Mechanical Drawing.—In the private colleges, 46.5 per cent of the students had not taken mechanical drawing in high school; in the public colleges, 58.0 per cent had not taken this subject. Of those who had studied the subject, approximately one-third had

studied the subject two years or longer; two-thirds had studied mechanical drawing as a one-year subject.

The Typical Engineering Freshman

From these data it is possible to hypothesize the typical engineering freshman enrolled in the colleges of engineering participating in the Project.[2] Bear in mind, of course, that this is a wartime freshman for the year 1944. His general characteristics may differ significantly from the typical freshman of the first few postwar years, but for purposes of record, let us summarize his principal characteristics.

Sex: Male
Age: 17 years at last birthdate
Birthplace: City—population over 5,000
High School:
  Type—Free, public high school
  Enrollment—500 or larger
  Location—Same state as college attended
High School Courses:
  Curriculum—College preparatory or scientific-technical
  Mathematics Subjects—
    Algebra—two years
    Plane Geometry—one year
    Solid Geometry—one semester
      or
    Plane Trigonometry—one semester
  Science Subjects—
    General Science—one year
    Chemistry—one year
      or
    Physics—one year
  Mechanical Drawing—Equally likely to have taken no course in mechanical drawing or one year of the subject.

The general characteristics of engineering students presented in this report have significance. Preliminary study of test results indicates that many of these factors bear directly on the success of individual students in the college of engineering. As we learn more about these factors and are able to relate them to student ability and accomplishments, examination techniques and guidance functions can be greatly strengthened and improved, thereby improving the whole process of engineering education.

[2] The word *typical* is used here in the statistical sense, that is, the median student in any distribution of student characteristics. When so defined, the word *typical* also has the more general meaning usually associated with it.

Education for the Engineering Profession

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The question whether education for the engineering profession, as for the older professions, should consist in a liberal education followed by a strictly professional education has been before the Society for the Promotion of Engineering Education from the beginning. The very first paper published in the *Proceedings,* entitled "The Ideal Engineering Education," by Wm. H. Burr (1893), proposed an affirmative answer: "In the older learned professions this sequence of a broad and general cultivation prior to, and forming the foundations of, the subsequent professional training, is well defined, and the ultimate nature of the case in engineering is precisely the same as that in law or medicine. . . . The writer unhesitatingly places, therefore, as the first and fundamental requisite in the ideal education of young engineers, *a broad, liberal education in philosophy and arts,* precedent to the purely professional training."

In the half century which has elapsed since this was written, there has evolved a normal pattern of engineering education which *seems* to be in another direction: an undergraduate curriculum in engineering, usually of four years duration, followed by a year or more of graduate study for a select group.

However, this normal pattern has tended more and more toward the earlier ideal through the gradual recognition, on the one hand, that the engineering curriculum should include ample courses in the humanities and, on the other hand, that engineering subjects themselves have an important cultural value. The trend is indicated by the following recommendations in the 1940 Report on Aims and Scope of Engineering Curricula, which are reaffirmed in the 1944 Report on Engineering Education after the War:

> Undergraduate curricula should be made broader and more fundamental through increased emphasis on basic sciences and humanistic and social studies. This will require greater efficiency in the use of the student's time, to be gained by pruning to the essentials of a sound educational program.
>
> Some of the advanced technical subject matter now included in undergraduate curricula should be transferred to the post-graduate period where it may be pursued with a rigor consistent with preparation for engineering specialization.

It is the purpose of the present paper to urge the fulfillment of the early ideal by such further modifications of the undergraduate curriculum as to make this truly liberal, while retaining its function of pre-professional engineering education, and by corresponding modifications of the graduate curriculum to provide the strictly professional education.

That education will be most deserving of the characterization "liberal" which provides the fullest understand-

ing of the contemporary world. It must link with the past through courses in history and literature; it must include the timeless basic sciences; but it must not disregard the present, the period in which human living is so strongly conditioned by the extraordinary advances in engineering. Thus the engineering type of education, possessing all these elements, is more truly liberal than the unbalanced education commonly provided by the colleges of liberal arts.

The principal modification required in the undergraduate curriculum is a broadening *in engineering itself.* Strangely enough, the 1940 and 1944 Reports, with all their insistence on breadth outside of engineering, still take it for granted that the engineering courses will remain narrowly specialized. Papers protesting against such specialization in undergraduate curricula were presented to the Society in the first two years of the century, from one of which, "Excessive Differentiation in Engineering Courses" by Edgar Marburg, we may quote:

> The fact that most engineers find it expedient ultimately to confine themselves to the practice of some single specialty may be adduced as an argument not *for,* but *against,* similar differentiation in the preparatory courses. Every specialist should possess a fair knowledge of kindred branches. Without some breadth of view he cannot hope to rise to eminence. The greater the difficulty of acquiring such collateral knowledge in practice, the greater the need of its presentation in the schools . . . no wiser provision can be made against the vicissitudes to which an engineering career is peculiarly liable than may be found in the broadest possible course of preliminary study. . . . That specialization in engineering education is becoming increasingly important is by no means denied. But in the writer's view its place is not in the undergraduate courses. Its ligitimate province is to be found in graduate instruction, and there no limits need be set to its intensity.

But such views were not then acceptable to most engineering educators; and specialization became rampant in the succeeding years. (Stevens Institute of Technology has apparently been a unique exception, in continuing to give a single broad undergraduate curriculum in what is now called "general engineering.") Some reaction subsequently set in, but specialization still remains the serious organic weakness in undergraduate engineering curricula.

The student who completes an undergraduate curriculum *in general engineering* has the world before him! He has had the opportunity to estimate the relative attractions of each specialty; so he can intelligently pick out his professional curriculum. Or he may prefer to enter at once on an active engineering career, with the possibility of taking advanced work in an evening graduate school, either at once or after a few years' experience has shown him what he most needs. Or he may even prefer to enter some other field for which his broad education has supplied a suitable background, such as mathematics or physics on the one side and business administration or governmental service on the other.

The recognition has come gradually that engineering education is needed, not only for professional engineers, but also for executives and others in industries which depend on engineering. The distinction was clearly brought out by President Wickenden in his final report (1933) as Director of Investigations:

> We have characterized the college curriculum in engineering as functional

rather than professional. That is not to minimize its value to the professional engineer, but to emphasize its broader utility. A majority of engineering graduates do not enter a profession, unless we use that term in its loosest sense. Instead, they enter upon business and industrial careers in which technical knowledge is known to be useful, if not indispensable, expecting to advance to executive positions. A much smaller number, probably not more than a third of the whole body of graduates, advance into the more highly skilled and individualized status of the professional engineer.

An undergraduate curriculum should evidently be designed for both the professional and the non-professional needs. The objections to undergraduate specialization for the professional engineer apply in even greater measure to the non-professional graduates. How many students not having the professional aptitudes have been put through specialized engineering courses which they do not need and cannot use! We have testimony that specialization is not demanded by industry, in a recent paper by Boring, Stevenson and McEachron, which was endorsed by the S.P.E.E. Committee on Relations with Industry (JOUR. ENG ED., 35, 485 (1945)):

Engineering education in college must be concerned with engineering fundamentals rather than specialized design. . . . Many will take exception to these beliefs, pointing out that widespread acceptance of them would lead to a single unified undergraduate curriculum. At least one educational institution has done exactly that with success. In the General Electric Company little recognition is ever taken of the branch of engineering in which a person was graduated, as the requirements of any electrical manufacturer so combine the mechanical, electrical and chemical fields as to be almost inseparable.

But engineering colleges should not confine their attention—as they have in the past—to students who originally pick out a career in the broad field of engineering. There is an important class of young people for whom no proper provision has been made in our scheme of higher education: those who wish to understand the modern world as a whole and to play a constructive part in it, who realize that this world is based largely on engineering, but who are not attracted to the practice of engineering. *This is the class from which our future leaders in business and politics should largely be drawn.* For them, a liberal education of the engineering type should be ideal. With it, they also would have the world before them—and some of the abler ones might change their minds and go on to professional engineering!

Thus the liberal undergraduate curriculum designed for a common preprofessional training in all branches of engineering is well suited to two much larger groups: those who need an engineering background for work in industry and those who need it as an essential part of a broad culture. If this be admitted, we have left to consider how to design the curricula.

Ever since its organization, the Society has debated the question of lengthening the curriculum. But this is the wrong question and has no universal answer. The right question is, What should be the content of the liberal and the professional engineering curricula? When this has been answered, the number of years required can be worked out in accordance with local conditions: in the majority of instances four years will presumably continue to

be required for the undergraduate curriculum and a fifth year for the professional curriculum. But it would be quite practicable and highly advantageous to engineering education in general for some of the favored engineering colleges to arrange a three-year undergraduate curriculum, with the professional curriculum completed in the fourth year. The "favored" colleges are those which are accustomed to draw most of their students from the stronger secondary schools, so that entrance requirements can be high, and which possess faculties willing and able to reorganize methods of presentation and to cooperate in the design of a unified curriculum. A detailed suggestion for a three-year undergraduate curriculum has been discussed elsewhere.*

Competition between three-year and four-year undergraduate curricula should prove healthy to both. The three-year curriculum would be strong enough to justify accrediting and the granting of the bachelor's degree; it would include the common core of all the major branches of engineering, with at least a year's course in each, besides the engineering applications properly used to illustrate the courses in the basic sciences; and it would devote some 25 per cent of the total time to the humanistic-social studies. It would have to be carefully designed, with the utmost economy in time, so that it would lay a sufficient foundation for a professional curriculum in any major branch of engineering. No engineering electives or specialization would be feasible. The four-year curriculum, on the other hand, would permit more freedom: engineering electives in the fourth year might permit some specialization; or greater scope could be attempted in the humanities; or a pace could be set more suited to the slower students; or a start could be made at a lower level to make up for inadequate high-school preparation.

The professional curriculum should include options in general engineering and in the major branches. On a full-time basis, it should lead to the master's degree in one year. When further specialization is desired, additional years might well lead to the doctorate.

Putting professional education in engineering on a graduate basis should do much to secure for the professional engineer the same popular recognition that is accorded the members of the older learned professions.

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*Alan Hazeltine, "To the Master's Degree in Four Years," *American Journal of Physics*, 13, 160 (1945).

Explorations in Engineering Education

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It is a self-evident principle that the social, industrial, and cultural progress of a nation is dependent in a large measure upon the extent and effectiveness of its educational systems. The responsibilities of leadership and the advancement of the civilization of tomorrow must inevitably rest upon the shoulders of the students of today, and their ability to cope with the problems of their generation bears a direct relationship to the quality of education and character training which they are receiving today. Leading educators have accepted this challenge and have given serious consideration to the means of improving the structure of our educational institutions as well as the educational methods.

In the areas of engineering education, the Committee on Education of the Society for the Promotion of Engineering Education has set forth clearly and concisely the broad fundamental principles which serve to chart the course of engineering education in the post-war era.[1] The course, however, is a difficult one fraught with many deceptive detours and dangerous reefs, and a chart alone, no matter how perfect, cannot guarantee a safe voyage unless it is used in experienced hands and tempered with wisdom and discretion. The engineering and scientific professions have a realistic stake in the advancement of engineering education and, out of their combined experiences, they can contribute immeasurably to its progress.

Recently, Dr. W. L. Everitt,[2] in an article entitled "The Phoenix," set forth a number of constructive proposals for the improvement of engineering education. He extended an invitation to the Institute of Radio Engineers sections to discuss this subject at scheduled meetings. The invitation was enthusiastically received and eighteen sections held meetings. The reports submitted to Dr. Everitt's I.R.E. Committee on Education bear witness to the spirited discussions that resulted. Several of the papers submitted have been published in the I.R.E. *Proceedings*. This article presents an analysis of the principal recommendations appearing in the section reports with suggestions as to how these may be incorporated in our educational system.

Fundamental Objectives

In general, there appeared to be considerable agreement as to the fundamental objectives of engineering education. These are in essential conformity with the objectives as set forth in the S.P.E.E. report previously re-

[1] Report of Committee on Engineering Education After the War, Journal of Engineering Education, V. 34, No. 9, May, 1944.

[2] W. L. Everitt, "The Phoenix," *Proc. I.R.E.*, V. 32, No. 9, September, 1944.

ferred to, and may be summarized as follows:

1. Mastery of the fundamental physical and mathematical laws and systems of measurement.

2. Development of proficiency in the methods of engineering analysis, a comprehension of the related elements in a problem, and the ability to synthesize the various elements to obtain a practical and economical solution.

3. An understanding of the principles of organization and management, with some knowledge of production methods and costs.

4. Development of the ability of organized, logical self-expression, both written and oral, and the faculty of motivating individuals and groups of individuals.

5. Comprehension of and the ability to analyze economic and social theories and problems; an understanding of the functioning of social institutions and their influence upon society and civilization.

6. Inculcation of a philosophy of life and a set of values including a professional attitude, moral and ethical principles, a sense of responsibility and eagerness to contribute to the advancement of society and the profession.

7. An appreciation of the higher forms of expression, including art, literature, philosophy, and music.

The first four objectives received the greatest consideration in the section meetings since they relate more directly to the engineering development of the student. Leading educators, on the other hand, viewing world social and economic conditions with considerable apprehension, have strongly emphasized the necessity of broadening the engineering curriculum along social-humanistic lines as set forth in the last three objectives, in order better to prepare the engineer for increased responsibilities in the management of industry and society.

Critical Selection of Instructional Staffs

Among the numerous recommendations appearing in the section reports, several stand out in bold relief. The necessity of obtaining competent instructional staffs comprised of individuals who have achieved high levels of scholastic attainment, who have acquired a background of professional experience, and who have the necessary personal attributes for successful teaching, was repeatedly emphasized. It may be accepted as a foregone conclusion that the success of any educational institution is dependent first and foremost upon the competence of its instructional staff.

There are circumstances, however, which are making it difficult for engineering colleges to obtain highly qualified instructional personnel. In recent years, industry has awakened to a recognition of the need for highly trained engineers and scientists and has drawn heavily from the reservoir of available teaching talent. Many of the better qualified college instructors have been lured into industry at salaries beyond the reach of the colleges.

The engineering colleges, themselves, have become conscious of their responsibilities in expanding the frontiers of scientific knowledge through organized research programs. This has been given added impetus by the success of war research programs in the colleges. At present, every indication points in the direction of more widespread federal, state, and industrial subsidization of research in the engineering colleges, and many of the more progressive colleges are mak-

ing plans to expand their research facilities and enlarge their research staffs. This will serve still further to deplete the reservoir of available teaching talent.

The armed force requirements have resulted in serious reductions in undergraduate enrollment in engineering and the sciences, and the number of students taking post-graduate work has dropped to an unprecedented low. This failure to replenish the depleted reservoir of instructional talent presents a serious problem in engineering college administration. The colleges have been compelled to recruit temporary instructors, many of whom are either not interested in or not qualified for permanent teaching positions.

In view of these considerations, it is apparent that the responsibility of the engineering colleges extends beyond the mere selection of competent instructional personnel, for it is equally important to develop high quality post-graduate study programs in order to enlarge the reservoir of available talent. Students who are qualified for post-graduate work should be encouraged to continue their studies toward advanced degrees, and financial aid should be made available where the need arises. A relatively large number of technician-trained men will soon be released by the armed forces. The better qualified among these should be urged to return to the colleges and continue their work toward engineering degrees.

Development of Latent Capacities

The one issue which consistently aroused widespread discussion, particularly among practicing engineers, appeared in the form of an urgent plea that more attention be given to the further development of those latent capacities of character, self-expression, professional attitude, judgment, and the ability to approach problems and situations with intelligence and self-assurance. Most engineers felt that sufficient time and emphasis, in bulk, are now devoted to the acquisition of technical knowledge and skills but that the importance of developing the vital human attributes is vastly under-rated in the engineering colleges. The opinion is frequently expressed that college instructors, in general, being academic-imparting specific knowledge and analytical methods *per se* than in arousing a vital enthusiasm and challenging interest within the student which will serve to bring out the important human attributes.

There are those who would relegate this problem of character development to specific courses in the engineering curriculum such as psychology, public speaking, or even English, and absolve all other instructors from any responsibility in this area. Then there are others (too often the college instructors) who dismiss the problem with the terse statement that the development of these human character traits is the function of the home and the church, or that they are best developed in extra-curricular activities and therefore fall outside of the realms of educational responsibilities. Such proposals, however sincerely offered, are predicated upon the false assumption that education and character training are two separate and distinct processes, each to be treated in its own sphere, and that the two are not to be combined.

In industry we find those who declare emphatically that the development of the character, abilities, and capacities of the student constitutes the foremost responsibility of the colleges.

and that the acquisition of knowledge and skills is of little avail unless the other attributes are developed to the fullest possible extent. Reflecting upon their own education in retrospect, they are frank to admit that most of the knowledge which they once acquired in college has long since vanished, but that the training in the powers of analysis, judgment, self-expression, and character development are the sturdy foundations upon which to build successful careers. They claim that the formal lecture method of instruction, which seems to have become firmly entrenched in our universities, is often a boresome and inefficient method of teaching. Its principal virtue is that it contributes to the self-edification of the instructor and serves to develop his oratorical powers. A few instructors who are endowed with exceptional personal characteristics or who have acquired outstanding professional reputations are able to inspire the genuine enthusiasm and vital stimulation necessary for successful teaching but, more often than not, the converse is true.

A critic would ask us to sit in on a typical lecture (which we find to be a little on the boresome side) and observe the response of the average student. We are likely to find him listening in a half-hearted sort of way with mental processes laboring along at subnormal efficiency, dutifully taking notes but otherwise assuming a passive interest in the whole affair. A little later they point out the same student who has now become enthusiastically engrossed in some extra-curricular or athletic activity where he finds a vital interest and a challenge to his abilities. In contrast with the attitude of mental fatigue experienced in the classroom, we now find him eagerly planning, figuring, and working, with mental processes shifted into high gear. Our critic then asks, "Why can't we stimulate that kind of enthusiasm in the classroom?" If this were only possible it would result in an astounding increase in educational efficiency! What are the principal motivating factors which make sports and extra-curricular activities so palatable, yet which are normally lacking in the classroom? In seeking an answer to this question we discover the following:

1. In sports and extra-curricular activities the student becomes an active participant and takes a challenging part in the undertaking with complete freedom of expression and the freedom to exercise his own ingenuity. In the lecture type classroom, the instructor takes the active lead and the student's part is subjective and passive, thus failing to arouse any vital stimulation in the student.

2. In sports and extra-curricular activities we find a keen sense of teamwork and competition, which add spirit and zest to cooperative undertakings. This is usually lacking in the classroom.

3. In extra-curricular activities the student undertakes project-type responsibilities which tax his ingenuity and challenge his ability. This may appear in the homework assignments but is not often present in the classroom.

Is it possible to devise instructional methods which will incorporate these elements and still maintain the orderly continuity and rate of progress necessary satisfactorily to cover the course material? Perhaps we can profitably take a chapter from the experience of industry where the conference method has proved so successful in the training of foremen and executives. In a successful conference, the conference members are given advance notice of

the agenda and have specific assignments to prepare. The leader opens by stating clearly and concisely the aims and objectives which are to be realized in the conference. The group then collectively formulates a method of approach and proceeds to develop the problem. Active participation is encouraged from all members of the group. The conferees present prepared reports which are discussed by the conference members. It is the responsibility of the conference leader to guide skillfully the course of the discussion with a view toward attaining the objectives.

The conference method has much to offer in our college instruction programs. It serves to stimulate interest and enthusiasm through increased participation of the individual. It serves to develop sound and logical thinking, the ability of self-expression, and a professional attitude since the individual becomes the focal point in group discussions rather than the instructor. This method of instruction requires careful planning and skillful guidance on the part of the instructor in order to keep the discussion moving along proper channels and to attain the desired objectives. Although the conference method is best suited to small classes, it has been successfully applied to relatively large groups on a more formal basis. The principal limitation of the conference plan lies in the fact that it is difficult to maintain the same rate of progress as in the lecture type of course where the instructor presents the material in the orderly, logical pattern which he has found best from personal experience. However, there is scarcely a course in the engineering curricula which would not profit by a generous application of the conference method and the returns, by way of stimulating interest and developing the potential capacities of the student, would be most gratifying.

As emphasized by Dr. Everitt, wherever possible, typical engineering problems should be assigned which combine the elements of synthesis and analysis in such a way as to tax the student's ingenuity and develop the engineering method of approach. A single project-type problem may very profitably comprise the assignment for several days or several weeks. The assignments should be such as to require frequent reference to technical publications and the students should prepare material for oral presentation to the group. The broader aspects of economic, social, and ethical considerations should be freely discussed wherever they arise. Engineering and science should be taught as a dynamic body of knowledge which is constantly expanding and the limits of present-day knowledge and direction of expansion should be discussed.

In the project type of laboratory, we find a means of acquiring experience in the engineering method and developing creative thinking. Here a small group of students selects a project type experiment in consultation with the instructor, plans the method of approach and equipment to be used, and carries it through to a successful conclusion. The number of experiments conducted in this type of laboratory is considerably smaller than in the cook-book variety of laboratory where the student is handed all of the ingredients and a set of instructions on how to mix them to produce the desired results. However, the mental processes which the student goes through in developing the project type experiment are

similar to those experienced in engineering practice.

Universities are frequently open to the criticism that they fail to train adequately new instructors in efficient and effective teaching methods. Too often it is taken for granted that a young instructor who has a master's degree or a doctorate degree has enough intelligence and resourcefulness to devise successful teaching techniques of his own. The new instructor, however, is likely to find the demands upon his time weighing heavily. He is expected to continue his advanced studies, carry on research work, and develop himself professionally in addition to his routine departmental responsibilities. Consequently, he finds little time to develop the fine art of teaching. Successful teaching is a skilled art, and one in which the new instructor can profit immeasurably by the experience of others. In many cases the efficiency of instruction could be greatly improved through definitely scheduled and planned conferences in which the new instructors would have an opportunity to discuss educational methods as well as their own particular problems with experienced instructors.

Correlation of Mathematics, Physics, and Engineering Courses [8]

The need for better correlation of the mathematics, physics, and engineering courses is always a favored topic in discussions on engineering education. Here we find two camps with diametrically opposed viewpoints. The first camp contains critics who contend that mathematics courses are all too often taught in the nebulous abstract by puritanical mathematicians who are scrupulously careful not to contaminate a beautiful science with practical applications. The critics argue that the student fails to appreciate a beautiful science in its pure form, and merely learns to perform mechanical manipulative processes without the slightest comprehension of the ultimate use. Later the student encounters engineering applications and is deeply distressed and confused by the fact that the mathematics here bears little resemblance to that through which he had previously struggled. To the critics in this camp, the solution is quite obvious. They contend that mathematics should be taught as an applied science, with each new mathematical principle introduced by way of a physical problem. It is contended that the physical concepts serve as a visual aid to guide the student over the difficult mathematical steps toward an eventual solution.

In the second camp we find the equally ardent opponents of the applied mathematics viewpoint. They argue that the student who receives the mathematical principle and the physical application simultaneously is compelled to grasp two concepts simultaneously, neither one of which is familiar to him. This mental juxtaposition often results in confusion and the failure to recognize the fundamental mathematical principle. Furthermore, they contend that the applications are invariably special cases of a general theory and mathematics taught in this way is deprived of its generality, rigor, and clear-cut demonstration of fundamental principles.

A compromise approach might offer a reasonably satisfactory solution to

[8] See E. A. Guillemin, "Coordination of the Work of the Physics, Math., and E.E. Staffs," Journal of Engineering Education, V. 35, No. 7, Mar., 1945.

the problem. Thus, the fundamental mathematical principle could first be presented in its pure form. This is then followed by illustrative examples in which the principle is applied to physical problems well within the grasp of the student. Such an approach would require that the mathematician know something about the applications of mathematical principles. Typical illustrative examples could readily be furnished by the physics and engineering departments and it might prove beneficial to have the mathematics instructor sit in on physics and engineering courses.

There is also a need for closer correlation among various engineering courses. In the fields of statics and dynamics, fluid mechanics, thermodynamics, and electrical engineering we find many similarities in analytical methods. The courses should be taught in such a manner as to emphasize these similarities and thus break down the compartmentalization barriers which have grown up between our engineering courses. Advanced courses in engineering mathematics have already accomplished much in serving to break down these departmental barriers.

Degree of Specialization

The issue which invariably provokes the sharpest discords of opinion in round-table discussions among engineers and educators is the question of whether the major emphasis in the engineering curricula should be placed upon (1) a broad general engineering education, (2) highly specialized engineering courses of the practical variety, or (3) highly analytical but fundamental engineering education.

An executive engineer in a large corporation states that his experience has shown that the majority of graduate engineers eventually become engaged in design, production, or sales work where they have little use for the highly analytical course material taught in many engineering courses. On the other hand, most engineers need more knowledge of materials, mechanical design, production methods, costs, and management. These are the elements with which the average engineer works in everyday engineering practice. A prominent radio engineer arises to decry the fact that graduate electrical engineers who enter the radio profession may know Maxwell's equations forward and backward but they flounder in hopeless confusion when confronted with a job of designing simple circuits for a radio receiver. He contends that there should be an electronic curriculum for students desiring to enter the radio profession, and that this curriculum should emphasize the design of radio and electronic circuits, materials, and equipment.

A leading educator hastens to remind us that, up to the last couple of decades, the majority of foremost engineers in this country, the Steinmetzes and the Timoshenkos, received their education in European universities where the major emphasis was placed upon analytical subject material. He points out that in recent years American engineering colleges have placed increasing emphasis upon analytical methods with the result that the American trained engineer now attains a professional stature comparable to the European trained engineer. Therefore, the continuation of American engineering supremacy requires that greater stress be placed upon fundamental analytical material in the engineering curriculum with a unifying of

the underlying continuity throughout all of the physical sciences and engineering courses. Furthermore, he contends that the practical aspects of engineering can be learned much more thoroughly and with considerably greater facility in industry, whereas in college the student should concentrate upon developing analytical abilities.

He would remind us that much of the material which we now consider as basic in the engineering curriculum was either unknown twenty years ago or was frowned upon as being nebulous, unintelligible theory which had no place in the engineering curriculum. As an example, he cites the theory of modulation which was first presented by Carson scarcely twenty-five years ago. At that time, modulation was considered a mystifying and highly theoretical subject which only the physicists and mathematicians could hope to fathom. Yet, today this theory is given in practically every undergraduate radio engineering text book and even the die-hard radio engineer would insist upon its inclusion in the electrical engineering curriculum. In view of the spectacular progress being made today in physics and engineering, we can set it down as a foregone conclusion that the engineering curriculum twenty years hence will contain many new fundamental scientific and engineering principles and it is the responsibility of the engineering instructor to ferret out the truly fundamental concepts and put them up in presentable form for the undergraduate curricula. He declares emphatically that when the time comes when we cease to bring down into our undergraduate curricula new scientific and engineering fundamentals, then engineering progress will have reached stagnation and we will be well on the road to decadence.

A distinguished individual arises. "Gentlemen," he begins, "the evidence presented in this round-table discussion clearly and decisively points to one inevitable conclusion. In order that our engineering curriculum encompass the rapidly expanding technological advances and, at the same time, provide the breadth necessary for a proper understanding of social, economic, and political elements in our society of today, the engineering curriculum must be extended to include at least five or six years. The training of doctors and lawyers extends over a period of seven to ten years. Is it therefore asking too much of the engineer to devote, let us say, six years of his life to his professional development?"

A conservative engineer calmly counters with the reminder that there are other factors which must be considered when making decisions affecting the duration of the undergraduate engineering curriculum. Thus, the majority of engineering students receive their baccalaureate degree between the ages of 22 to 25 years. This is the age of life at which young men should seriously think of getting married, raising families, and embarking upon a professional career. Regardless of how thoroughly the engineer is trained in college, he still must spend an apprenticeship in industry before he can become an experienced and valued engineer. It is better that he complete this apprenticeship at an early age. Doctors and lawyers start their principal life work at about the age of thirty. This is entirely too late a start for the average engineer both from a sociological and a professional viewpoint.

He would also like to remind us that

those of us who expect the young student, emerging from a chrysalis of college education in a somewhat faltering state of mind, to be thoroughly grounded in scientific and engineering principles; to have a broad comprehensive training in design, materials, production processes, and costs; to have an intensive training in a field of specialization; to have an adequate background of social and humanistic studies; and to possess professional maturity and experienced judgment are expecting far too much of human nature. He points out that the problem of inculcating this conglomeration of virtues in an orderly and coherent pattern in one stable individual is quite analogous to undertaking the intricacies of teaching muscular coordination to a paralyzed centipede. Even the mature engineer seldom possesses all of these multidinous virtues. He expresses the firm belief that the engineering curriculum should concentrate largely upon the logical and orderly development of scientific and engineering fundamentals, with a moderate amount of emphasis placed upon the broad cultural subjects and business courses. The engineer can then acquire specialization and a further knowledge of business methods during his apprenticeship in industry. Our present system of daytime and evening graduate courses offers ample opportunity for the engineer to further expand his education along scientific, business, or cultural lines.

And so the battle-royal rages on!

At this point, we turn to the engineering educators and ask of them what they propose to do in this dilemma. In the S.P.E.E. report, we find clear-cut recommendations for many of our inquiries. This report recognizes the need of dividing engineering students into three categori classified as: (1) the largest porti comprising students pursuing a nor engineering curriculum, (2) stude preparing for operation and mana ment pursuits, and (3) the scientifi technical group. All three gro would receive the same broad gene courses in the physical sciences and e gineering fundamentals. In the sen year the second group would take a ditional courses in production met ods, management, cost accounting, a other business courses. The thi group would pursue a planned and c ordinated sequence of science and e gineering courses extending throu the last two years of the undergradua curriculum and into the graduate pr gram.

This committee recommends that t undergraduate curriculum include thorough grounding in the broad funda mentals of the sciences and enginee ing, an integrated sequence of cours in social, humanistic, and busine studies, and a moderate amount specialization along the lines of furth developing fundamental principles a particular field of specialization. recommends that some of the more sp cialized engineering material no taught in the undergraduate curricu be transferred to the graduate progra in order to clear the way in the unde graduate curricula for higher priori material of a more fundamental natur It is fully cognizant of the fact th this program will not turn out exper enced and mature engineers, and i dustry must therefore assume t burden of training the student alon specialized lines required for the pa ticular industry.

Rather than extend the duration the undergraduate engineering cu

ricula,[4] the committee recommends concentrating attention upon: (1) making a critical selection of course material, (2) providing a better correlation of material and improving the underlying continuity of courses in the engineering curriculum, and (3) improving the effectiveness and efficiency of instruction methods.

The committee has strongly emphasized the importance of providing for a carefully planned and coordinated sequence of social-humanistic courses. It is becoming increasingly apparent that many of the larger and more difficult problems facing the engineering profession today are of a social, economic, or political nature. The engineer must take his full share of responsibility in the solution of these problems or democracy and the engineering profession will surely suffer. Education for democracy is fully as important as education for a profession. This portion of the educational program would include a fundamental treatment of (1) the individual and his environment, including an analysis of factors contributing to the rise and degeneracy of ancient and modern civilizations; (2) the functioning of social and industrial institutions, including labor and management problems; (3) economics of our modern industrial society; (4) an analysis of political systems; and (5) moral, ethical, and social philosophies.

The issues discussed here are but a few of the more controversial problems facing the engineering colleges. Space limitations preclude a discussion of many of the problems considered at the section meetings. Several of the less controversial issues included: the necessity of improving the selection of students admitted to engineering schools; the need for better mathematical preparation in the high schools; the desirability of having students and faculty members alike supplement their engineering education with experience in industry; and the need for stimulating research in engineering colleges as a desirable adjunct to engineering education.

The problems discussed here are, in general, not amenable to clear-cut decisions based upon tangible evidence alone, but rather must necessarily reflect the combined experiences of industry, educators, and the engineering profession. A free interchange of ideas is vitally necessary in order to assure an enlightened viewpoint as a basis for intelligent decisions. In the final analysis, however, the destinies of engineering education lie in the hands of the individual instructors in the colleges; theirs is the privilege and the obligation of assuring American supremacy in engineering education.

[4] For a discussion on extension of undergraduate program see H. J. Gilkey, "Discussion of S.P.E.E. Committee Report on Engineering Education After the War," JOURNAL OF ENGINEERING EDUCATION, V. 35, January, 1945.

Can Humanistic-Social Study Be Made Engineering Education?

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Among engineers and engineering educators there is a widespread conviction that an exclusively scientific and technical education, no matter how good, needs to be supplemented by humanistic-social study if the student is to be adequately prepared for attaining full stature in his profession, in his community and in his personal life.†

Humanistic-social courses, however, are not inherently engineering education. Since engineering students come to college to study engineering, they tend to treat such courses as sidelines, to study them halfheartedly, and to seek to get through with them, not to master them. All too often such courses promote habits of loose thinking in regard to social and human problems, and the attitude that such problems do not require of an engineer the careful orderliness and thoroughness of thought which engineering problems do. Consequently if humanistic-social studies are to play their part, it is vital that they be made to take hold of the mind of the student as part of his engineering education.

But can this be done? Certainly no amount of preaching or indoctrination will do it,—nor will the citation of authority, no matter how high. Nor will a wise selection and arrangement of humanistic-social courses in itself weave them into the warp of engineering education as an integral part of its fabric and make them cease to be a fringe. Some other way to make these courses engineering education must be found. To do this it is helpful to get clearly in mind the aims they are expected to fulfill.

The aims of humanistic-social study can be briefly stated. They are to prepare the engineering student to learn from study and experience throughout life to serve society, to live his own life well, and to work well with others. This brief statement summarizes the objectives adopted by the S.P.E.E. and the E.C.P.D. but also adds "to work well with others." This has been added because few abilities which humanistic-social study can assist the student to develop are as important to the engineer in filling his place in his profession and in his community as the ability to work effectively with others, be they clients, customers, colleagues, superiors, individual employees or employees organized in labor unions.

* Much of the material for this article was developed in cooperation with the faculty at Carnegie Institute of Technology where I was visiting professor.

† See "Report of Committee on Engineering Education after the War" (JOURNAL OF ENGINEERING EDUCATION, Vol. 34, No. 9, May, 1944, p. 594).

In preparing the engineering student to fulfill these three general aims, it is important to bear in mind that the task of humanistic-social study is not to provide fullness of knowledge. Instead the task is to help the engineering student to develop skill in using the fundamental knowledge and disciplines of the humanistic-social fields to reach his own decisions in meeting the problems of his study, his work and his life; and, equally important, skill in learning from doing this.

Regardless of the intent of the instructor, a student learns in his courses, as in life, only from what he thinks and does. Moreover he learns from all that he thinks and does in connection with his courses whether it is what his instructor wants him to learn or not. Consequently the only way that humanistic-social instruction can help the student gain skill in problem-solving and in learning is to establish courses which provide exercise of these skills by the student. And the only way to make such instruction engineering education, and not just a fringe upon its fabric, is so to plan and conduct these courses that in them the student uses engineering knowledge, tools and ways of thought in dealing with content of significance to the engineer.

To illustrate how this can be done, assume for instance that it has been decided that English composition is a humanistic-social study with sufficient promise to justify a place in the engineering curriculum. This immediately raises the question: what knowledge or skills can instruction in English composition provide which will be useful in subsequent study in engineering college, or in the later life of an engineer; and which are so fundamental that they can better be learned in advance than at the time of use?

The answer to this question can best be found by examining the situations in which engineering students and engineers use written and spoken English, and determining the skills which these situations call for. Outstanding among such skills, for instance, is skill in arranging concrete material and scientific principles into logical and unified written statements which are complete, accurate, and clear. The need of this skill in close scientific thinking, as well as in communicating important scientific and technical matter to others, is unquestionable. And as President Doherty of Carnegie Institute of Technology has pointed out, "the discipline in scientific thinking which this process gives is as essential a part of technical training as is the use of physics and mathematics in engineering study." The development of this skill in a course in English composition will thus help the student in almost all future engineering courses, and its exercise in these later courses will strengthen and deepen it.

Skill in adapting what one writes or says to one's reader or hearer, to cite another instance, is likewise a basic need of engineers. For often in making a technical matter clear to others an engineer must adapt his statements to their intelligence and in other circumstances he must speak or write with consideration of the feelings of others, or of his relationship to them.

Both of these skills are not merely broadly useful to engineers, but also relate to fundamental problems of English composition. To teach such skills involves exercising the student in the essential disciplines of using English to clarify thought or communicate it to others. By concentrating on such skills the content of English composition can both be kept broad and funda-

mental and yet be brought within the scope of engineering education.

The basic way of thought which English composition uses and inculcates can similarly be related to the resourceful and well-ordered method of handling problems that is characteristic of the trained engineer. For the stages which are involved in the engineering method—defining the problem, planning its treatment, executing the plan, and checking the work as a whole—are also inherent in the well-ordered handling of the problems of English composition.

Take, for example, the stages involved in solving such a problem as that of writing a statement which will make clear to a person who has never studied physics what a physicist means by "work." To write such a statement properly it is first essential to *define the problem* by making a careful logical "outline" of just what "work" mean in physics—*i.e.* of what the writer wants to bring the reader to understand. In order to translate this "outline" of the problem into a written statement it is next important to devise *a plan of treatment*—a strategy of how to start with what the reader knows—and give him the power to go step by step until he has reached the desired understanding of "work." Then it is necessary to *execute the plan* by writing the composition in full. Finally it is important to *check the work as a whole* in order to see if what is written does the job as it should and if not to amend it so that it will do so. The similarity of these stages to those involved in handling an engineering problem is so great that it is not difficult so to treat problems of English composition that the student becomes aware that he is using engineering methods.

If English composition is taught in terms of problems significant to the engineer and if in solving these problems the stages of disciplined engineering thought are made apparent to the student, English composition ceases to seem irrelevant and discouraging to him. Instead it becomes engineering work which he can do by using the way of thought for which he has aptitude and in which he is being trained in his scientific and technical study.

The other humanistic-social courses which can justifiably be included in the education of an engineer can similarly be woven into the fabric of engineering education. History can be taught so as to emphasize the interrelation of the growth of technology and the way of life, the government, the international relations, the social institutions, the intellectual culture and the religious beliefs of men and nations. When so taught it becomes an exploration of the origins and nature of the problems, forces, and institutions with which the engineer must deal in his profession and in his community. History also gives an exceptional opportunity to teach the art of finding, sifting and appraising evidence in determining the significant problems and factors in a complex factual situation. The skill in inductive reasoning which such study helps to develop is of great importance to the engineer in dealing with mature professional situations, but is exceptionally difficult to teach in undergraduate scientific and technical study.

Since economics is largely concerned with the treatment by analytical methods of problems significant to engineers, it can be brought fully into the main current of engineering education by emphasizing the relation of its problems to those of the engineer, and by

employing mathematical techniques and the engineering method of problem analysis in handling them. Psychology, by omitting much conventional subject matter, by utilizing the analogies of physical science, and by focusing its instruction upon developing skill in using its fundamental principles in the engineering task of solving problems of human relations in industry, can be made directly to equip the student to use engineering discipline in working well with others.

Even in teaching art, music or literature, the possibility of bringing the study into the current of engineering education exists. Since the purpose of such courses is to expand the mind and spirit of the student, it is essential to take him beyond the range of engineering subject matter. But it is not necessary to do so "all at once and nothing first." It is possible to start where his interests lie and his capacities are, and then to help him to find the way from this to a type of art, music or reading that, while satisfying to his interests and suited to his capacities, is both broadening to his mind and exalting to his spirit. Moreover, by assisting him to discover the problem of the composer, artist, or author, to explore his plan of treatment, and to see how he executed that plan, the course can help the student to see more deeply into literature, music or art with engineering eyes, and to make those eyes more sensitive to all that is good in life.

In each of these fields, the process of making a humanistic-social course an integral part of engineering education is the same. It is first necessary to discover what of its knowledge, tools and ways of thought would, if properly taught, be of basic value to the engineering student in later study or work, to focus instruction on this, and to devise means of teaching this so that it will be most useful in later learning or activity. Then the task reverses its direction and becomes one of finding what in prior scientific-technical courses can be made useful in the present course, and of teaching that course so that these engineering elements, be they knowledge, skills, or fundamental ways of thought, will be most effectively used.* When this is done, it is astonishing how extensive and fundamental the common elements are and how much value can be derived from taking this into account in teaching.

It is of utmost importance in thus making humanistic-social studies engineering education to remember that every hour of instruction used for such studies is subtracted from the already too limited time available for scientific and technical study. To teach humanistic-social subject matter merely because it is a conventional part of a course or to introduce practical information merely because it is immediately practical is an unjustifiable dissipation of what is truly "borrowed time." For the task is not to teach either conventional or applied knowledge, but to teach the art of using knowledge, principles, and fundamental ways of thought in later study and life; and the test of what subject matter should be included in a humanistic-social course in engineering schools, is how effectively it contributes to doing this.

* Although the process of fundamentally relating the humanistic-social courses to engineering, by giving them a common core of tools and ways of thought, will in itself go far in interrelating them to each other, this reciprocal interrelating of courses can and should also be directly done between humanistic-social courses themselves.

Information and subjects that fail to meet this test should be excluded from engineering courses no matter how firmly they are imbedded in the traditional course content. Narrow technical forms, such as those of report writing or engineering bookkeeping which, although probably useful applied knowledge, are not fundamental tools of learning, should similarly be excluded. They are detached and inert knowledge which can be quickly learned at time of need. They do not give the student flexibility and power to grow but tend to rigidity and artificiality. They are neither fundamental enough in character nor broad enough in reference to justify teaching them except as incidental to their immediate use.

Usefulness to an engineer in future learning and development, however, must not be conceived of narrowly as practical usefulness. Instead it must be conceived of broadly as usefulness in deepening understanding, enriching experience, strengthening moral purpose and otherwise developing all that is good in man. Narrowly utilitarian humanistic-social study defeats the very purposes for which such study is introduced into the engineering curriculum. Instruction in humanistic-social studies that is broadly and fundamentally useful engineering education, on the contrary, can do more to expand the interests, insight and spirit of the engineering student than instruction which remains outside of the main structure of his education.

To interrelate the humanistic-social courses with the scientific-technical ones in their fundamental aspects not only joins these groups of courses in a common engineering education but strengthens the quality of instruction in both. It emphasizes what is fundamental, and by the frequent re-use of fundamentals in different courses promotes thoroughness of learning. It insures that what the student learns is not to talk about but to use the concepts, tools and ways of thought of each field.

Interrelating the humanistic-social and the scientific-technical courses also indicates to the engineering student the underlying unity, throughout scientific, technical and humanistic-social study, of scholarly workmanship, attitude, and style. By causing him to think his way out with engineering care and orderliness even when faced with perplexing problems to which mathematic manipulation cannot give full means of solution, it helps him while still in college to render his skill in engineering analysis flexible, resourceful, and free from dependence on prior formulations. It thereby makes this skill available for understanding human and social, as well as technical problems, and causes his professional development to enlarge his capacity to take his place in the world as a competent and responsible citizen.

Are We Overemphasizing Science and Technology?

By DAVID L. ARM

Professor and Head, Dept. of Mechanical Engineering, Iowa State College

Much has been said and written about the dangers of overemphasis of scientific and technica' education during the past several years and in the post-war era. Frequently one reads in the newspapers reports of speeches or papers on this subject and the "learned journals" (embracing certain non-scientific fields) continually publish papers on this subject.

This type of publicity has, in general, one of two "theme songs." The first seems to go something like this, "Oh, yes, the scientists and engineers have done a wonderful job in winning the war, but the humanities must win the peace." The second says, "We must decide whether we should educate for living or for earning a living." So far, scientists and engineers have been strangely silent on these subjects and public rebuttal has been little in evidence. The writer suspects that this is because scientists and engineers are too busy working to win the war *and* the peace to have time to reply.

Let us examine the first of the arguments being advanced, since the winning of the peace is of almost immediate concern to all of us. It is the considered opinion of this writer that it will be vitally necessary for the United Nations to send delegations to the peace conferences which will represent not only the humanities but science and technology as well. The problems will be so vast and complicated that the best minds in all fields of learning must be applied to them in order to arrive at conclusions which will establish a just and lasting peace. Problems of political science, government and law, medicine, religion, business and trade, money and international exchange, communications and transportation, physical reconstruction, industrial rehabilitation and production, and agriculture are only a few of the subjects for which correct, workable answers must be evolved. Unless these questions are solved correctly at this time, we shall surely pass through the world cycle of 1919–1939 again. The presidents of five national engineering societies in the United States, the A.S.C.E., A.I.Ch.E., A.I.E.E., A.I.M.E., and A.S.M.E., have recently proposed a program of industrial control for Germany which, it is believed, would prevent that nation from ever preparing to wage war again, while at the same time affording the opportunity for the development of a peacetime economy essential to the welfare not only of Germany but also of Europe and the rest of the world. Unquestionably, all of the other problems are now receiving similar attention by the proper groups, and all suggestions must be carefully integrated into an overall plan. In other words, the winning of the peace is not the exclusive property of one group of

thinkers; like the winning of the war, it must be a cooperative effort.

The comments which we hear regarding the "dangers" of overemphasis on science and technology in post-war education are really an extension of the traditional defense of the Liberal Arts. This writer is at a loss to understand why such a strenuous and continuous defense must be presented. Surely there can be no conflict between "education for living and education for earning a living," as education in all fields is aimed at the accomplishment of both. A full life is attained only if one has the opportunity to be of service to his fellow-man. The education of a minister of the gospel, for instance, and the education of a scientist are directed to preparing each for a life of service to society. The master plumber contributes no less to the health, comfort and well-being of mankind than does the skilled dentist. The musician and the engineer both contribute to making this world a better and more pleasant place in which to live.

No one field of education has the exclusive advantage of teaching its devotees to think. Civil Engineering and Sociology can claim that distinction equally. The training of the engineer and the scientist, it is claimed, is largely factual—the same could be said for the training of the lawyer, and all three are trained by the "case system." Thermodynamics is much less factual than the average course in history—and certainly insists upon as much ability to think.

One selects his field of interest for one reason—because he believes that he is particularly well-fitted to enter such a field. If his choice has been wise, his formal education will fit him to enter into active participation in the work of that profession or vocation. After further education, in the form of experience, and the attainment of a degree of intellectual maturity, more and more opportunities to be of service to society in general present themselves. The rendering of such service will naturally be followed by the rewards of satisfaction and remuneration.

It seems reasonable, therefore, to assume that anyone, well trained in his field of interest, who uses that training to the best of his ability in the service of his fellow-man, can be said truly to live. He has the greatest satisfaction which can be had from life—the knowledge of doing well a job worth doing. The fact that doing such a job in such a way enables him to earn a comfortable living does not deprive him of the opportunity for a full, well-rounded life.

In regard to the charges of lack of culture of engineers and scientists, Herbert Fisher Moore, in the Illinois Alumni News of March 1931, has said, "Why should we call uncultured the man who knows thoroughly and broadly the history and philosophy of the heat engine, but is ignorant of the music of Brahms, while we hail as cultured the musician who is a master of technique and knows the field of harmony, but is contemptuous of the applied science which has made possible the modern pipe organ?

"The jack of all trades and master of none is not an admirable figure. The speaker believes that the jack of all trades and the master of one is an admirable figure, and is more deserving of the title of cultured man than is the super-master of one trade who despises all others."

Suggested Improvements of the Post-War Undergraduate Civil Engineering Curriculum*

By JOHN B. WILBUR

Massachusetts Institute of Technology

In attempting to summarize the principles that should underlie the planning of the post-war undergraduate curriculum in civil engineering, it will be helpful to formulate some rather definite recommendations, since to do so will perhaps stimulate further thought and discussion. But because I shall tend to be definite in my remarks, I trust that you will not infer that my present ideas are not subject to revision.

It is appropriate to give consideration at this time to changes in the post-war curriculum, not so much because basic educational objectives have changed during the war years, but because in many instances we find ourselves in a flexible state where modifications can be effected more easily than would have been possible a few years ago. Many schools will be undergoing changes in personnel. Those of us who have remained at our teaching posts during the past few years have, in most instances, devoted part of our effort to other activities which have broadened our outlook. Some of us, with temporarily lighter teaching schedules, can devote more than the usual amount of time to planning for the future. We can plan now, with the prospect of converting these plans into action at a not too distant time. I do not say that sound educational objectives have been modified to any important extent by the war, but I do say that with the ending of the war, we shall have an opportunity, such as may not come again for years, to achieve those objectives more effectively.

Before attempting to outline these educational objectives, I should like to suggest for your consideration the following propositions:

1. The educational program of an undergraduate course in civil engineering should be arranged primarily to develop engineers who will become leaders in their field, rather than men who will be satisfied with routine positions.

2. The course should be designed to benefit selected students of better than average ability, since it is from this group that the leaders of the future will be developed.

3. It is sound educational policy to place greater emphasis on the fundamentals of applied science than on subject matter that is primarily vocational, even at the risk of handicapping a graduate somewhat with respect to his first job.

4. Time spent in school should be devoted primarily to those subjects that can be taught efficiently at school, and that would be difficult to learn

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without adequate supervision, rather than to material that can be acquired after graduation without too much difficulty, or even advantageously.

5. Because of uncertainty as to the particular field in which a graduate will eventually find his career, much specialization should not be permitted, although a limited amount of specialization is desirable, since it identifies a course, adds interest thereto, and develops a student's judgment in making broader applications of basic theory.

6. The professional success of a graduate is greatly influenced by certain nonprofessional qualifications. A school has responsibility in aiding students to develop the qualities that will help them to become leaders.

I have used the word "leader" several times. It is pertinent that we should inquire into the meaning of leadership, and attempt to outline the qualities that should be developed if it is to be achieved.* Leadership has a dual meaning. A leader may be one who excels in a particular skill or technique, as exemplified by an outstanding designer or by a man of great personal achievement in research, or a leader may be one who directs the activities of other people in organized effort. To clarify the following discussion, I shall denote the man who is preeminent in a particular skill as an *expert,* while the term *leader* will be reserved for the individual who guides the efforts of other people. Because either type of leadership is worthy of development, it does not follow that each type requires similar qualifications. Such is not the case; in fact, the requisites of the expert are in some respects opposite to those of the leader.

The primary requisite of the expert is intellectual excellence. Other qualifications are certainly desirable, but without intellectual excellence, qualities such as industry and the personal qualifications that are important to social contacts, are not likely to make possible the development of an expert.

Before discussing the qualities which leaders should possess, let us consider briefly the activities associated with leadership. The leader must decide what is to be done, how and by whom it is to be accomplished, and when it is to be carried out. He must build and maintain an organization which is potentially capable of effective achievement. Finally, he must obtain the coöperation of the members of his organization, so that their potential abilities will be translated into coördinated action.

A leader must have ideas, but it is not necessary, nor is it possible that they shall all be his own. In a sense he is a clearing house of ideas. If he is to make people want to bring their ideas to him, and if he is to be able to use continually the ideas of other people without arousing their resentment, he must inspire their liking and confidence.

A leader must be able and willing to make decisions. He must have breadth of view, so that decisions will relate to the whole. He must not be afraid to make occasional mistakes.

In deciding how a thing shall be done, technical knowledge is important, but the technical training and experience of the leader himself are almost certain to have been limited to a relatively narrow range of activities.

* Some of the ideas included in the following discussion of leadership have been drawn from: "The Nature of Leadership" by Chester I. Barnard, published by the Harvard University Press, Cambridge, Massachusetts.

He must direct work in fields where his technical knowledge is superficial at best, and perhaps totally lacking. He must depend on others, but he must know on whom to depend.

The final measure of the success of the leader is the degree to which he can persuade the members of his organization to convert their potential abilities into coördinated and effective action. To obtain the necessary cooperation from other people requires an understanding of their aims and an interest in their personal problems. Successful persuasion cannot be built to any large extent on logic, because most people are emotional rather than logical.

As we review the activities associated with leadership, we see that intellectual excellence, while helpful, is not the primary requisite. An understanding of people is of far greater importance. The engineering educational system is particularly well adapted to the development of intellectual excellence, and hence to the training of experts. Let us, however, examine the effects of such an education on the development of potential leaders.

The engineering student concentrates on fundamental science and upon its applications; while so concentrating, he cannot simultaneously broaden his knowledge of men to any great extent. He deals with physical concepts, and is apt to apply these concepts to human beings. Training in analytical thinking teaches one to break a problem down into its component parts, while decisions necessary in leadership must be based on a consideration of entire problems. The study of abstract principles leads one to see the many sides of a problem, and may make decisions extremely difficult. Because intellectual training permits one to define certain problems clearly, one may grow to avoid problems that cannot be defined clearly, and hence greatly limit the scope of his usefulness. The engineering student develops intellectual excellence, but that excellence will not be helpful in leadership unless it leads to correct decisions, decisive action and successful persuasion.

I do not wish to discourage unduly the idea that engineering training can be consistent with the development of leaders, since intellectual excellence and technical competence are desirable for leadership, even if they are not in themselves sufficient. But it is well to be realistic and to recognize that since formal technical education contributes comparatively little to the understanding of one's fellow men, or to decisiveness, or to persuasiveness, the educator in engineering should be seeking for opportunities whereby he can aid students to develop their potential qualifications for leadership.

Students need, first, an understanding of people, and second, experience in leading. Both of these needs can be promoted by participation in extra-curricular activities, or any other functions that bring the student into closer contact with his fellow students or his instructors. The caliber of his instructors and the methods of teaching that they employ, may be far more important in developing leadership than the subjects included in the curriculum.

But if the curriculum is of secondary importance to the development of leadership, it is at least of first order importance in the training of the expert. I shall, therefore, outline what appears to me to be the proper educational objectives that should underlie its preparation. I shall not attempt to outline the detailed methods by which these

objectives can be reached, but I shall suggest, for your consideration, the goal toward which we should, in my opinion, attempt to move. These objectives are as follows:

(1) *Sound Training in the Fundamentals of Mathematics and Science:* This is an objective of great importance, and is likely to be covered by standard first and second year courses in mathematics, physics and chemistry. Consideration might well be given to further requirements in these fundamentals.

(2) *Sound Training in the Broad Application of the Principles of Mathematics and Science:* This is a second objective of great importance. The mechanics of solids and fluids should be stressed, and the principles of geology, electricity and thermodynamics should be included to broaden the professional base. Later, the emphasis in application should be directed to subjects such as structures, hydraulics and soil mechanics, that are of importance in all branches of civil engineering. Courses coming under this classification should meet the following specifications: They should deal with fundamental applications; they should train the student in methods of application; they should present a mental challenge to the student.

(3) *Limited Training in Specific Professional Applications:* Training in specific professional applications—that is, by professional electives or options, should be limited to the fourth year. Care should be exercised that professional electives do not become too specialized, or stray too far from engineering fundamentals.

(4) *Limited Training in Vocational Courses:* It is helpful to a student to have some vocational knowledge, especially in securing and holding his first job, but such training is of secondary importance in a man's ultimate success. Some subjects that are primarily vocational, such as surveying field work, structural detailing and engineering drafting, should be included because they afford an excellent opportunity to train a student in proper methods of working, but major attention should center on professional subjects. We should not be primarily interested in developing technicians.

(5) *Limited Training in Factual Knowledge:* Factual knowledge is necessary to the background of a well trained engineer, but subjects that are primarily factual should be minimized and an effort should be made to correlate factual knowledge with subject content that requires analytical reasoning.

(6) *Limited Training in So-Called "Business Subjects":* A consideration of economics underlies substantially all engineering projects, and this fact can be stressed to advantage, particularly in fourth year professional electives. It is, however, doubtful as to whether time should be subtracted from fundamental engineering subjects for so-called "business subjects," such as accounting.

(7) *Broader Training in the Humanities:* Subjects such as English, history, economics and the social sciences, which we may classify as the humanities, should receive greater rather than less emphasis in the program. Attention should be given to developing the ability of the student for self expression, which is a necessary qualification for success in any branch of the engineering profession. A man may be very well qualified technically, but if he is inarticulate or cannot express himself clearly and forcefully, he is under a serious handicap.

(8) *Development of Non-Professional Qualifications:* Deliberate steps should be taken to aid students to develop those non-professional qualifications, such as the ability to get along with people, that will be important in achieving professional success. More can be accomplished by force of example, by proper discipline in orderly habits, by encouraging participation in student life, by informal contacts with students, by methods of teaching, and by inspiration, than by special courses aimed at developing these qualifications.

To summarize, let us arrange the undergraduate curriculum in civil engineering to give the civil engineering graduate a broad professional base. Let us choose its content in such a manner that it will serve him, throughout his career, as a foundation that will give him proper support if he aims to become an expert and achieve preeminence in any specialized subdivision of the field. But let us teach our courses with an effort to help students to see problems as a whole, and to weigh entire problems with respect to each other. Let us make a genuine and deliberate effort to develop their breadth of view, so that engineering education, far from being a confining experience, may open the door to greater usefulness by developing the leaders of tomorrow.

Smyth Report on Development of Atomic Bomb

Copies of this report may be secured for 35¢ from the Superintendent of Documents, Government Printing Office, Washington, D. C. This "edition is the official edition issued as a publication of the Office of the Chief, Corps of Engineers, U. S. Army."

Some Comments on the Engineering Physics Curriculum*

By A. O. WILLIAMS, JR.
Assistant Professor of Physics, Brown University

Once, several years ago, I was drawn into that favorite undergraduate maelstrom periodically stirred up for their instructors, a symposium on *Religion and Science*. In fact, fascinated by the wording of the invitation, I could hardly decline. The student who delivered it explained that several men of both academic and ministerial training would discourse on religion, a senior member of the engineering school would uphold "the applied sciences"—and would I agree to represent "the useless sciences"? I fear he viewed it as a joint lowering in subject and defender. It is hard to know just what role a physicist should take in the battle royal so easily stirred up among the fields of engineering, pure physics, applied physics, and engineering physics, but I *am* sure that none of these deserves the description "useless."

There probably should be some sort of distinction drawn and retained between the fields of *applied* and *engineering* physics. However, different individuals have very different opinions in this regard, some even denying the need or significance of such a distinction. A suggestion as to the difference between the two may be ventured: That an *applied physics* curriculum has connotations which place it beyond the reach of most colleges, for the name suggests a self-contained unit, taught by a staff including some members with both academic skills and wide experience in applied work—industrial research, development, and testing; instrument design; the borderline fields such as chemical physics and biophysics. In remarking that such a teaching staff would be unattainable for all but a few of the largest institutions, I by no means wish to suggest as my belief that an engineering physics curriculum is simply a reluctantly accepted substitute for one in applied physics. While this view is held by some, it seems that the origin and development of engineering physics curricula, as well as the constantly growing interest displayed in discussion and teaching in this field, offer a strong rebuttal.

As an added point, a few schools with traditionally strong physics curricula can continue to place their graduates with relative ease in either pure or applied physics positions. For most smaller schools, however, there should be a strong and useful appeal to industry in the name of an engineering physics curriculum. For this ought

* Presented at the symposium on the Engineering Physics Curriculum, at the meeting of the New England Section of S.P.E.E., at Harvard University, on October 7, 1944.

to and can be a valid guarantee that their physics graduates have been conditioned by and to elementary engineering training, with consequent promise of fitting better into industrial work.

I do not intend rashly to attempt a definitive discussion of engineering physics, nor of the best curriculum in it. Instead, I shall propose a few questions and amplify them somewhat, in the hope that others may carry on a more able treatment of them.

In an engineering curriculum, are not the actual course or subject names of secondary (not necessarily slight) importance? Is not the greater need for an indoctrination, a morale, a professional philosophy of the students concerned? Consider the indoctrination of college students in pure physics, now of long standing. It has apparently been well suited to propagate the academic species, to reproduce professors and researchers. However, it is widely conceded (and this is sometimes far too weak a word) that it has failed to provide nearly enough men inclined and adapted to the practice of applied physics.

Contrast the generally successful indoctrination of engineering students, who learn to tackle practical problems in hard-boiled practical fashion. At its best, such training cuts through much theoretical wool-gathering, though at its worst it may leave the average graduate at a loss before novel situations, and inclined to pile up unwieldy structures of known procedures instead of producing an original solution. Beyond doubt, however, the morale aspect of such engineering indoctrination is high, and it conditions graduates for the work most of them will meet.

While the details of course requirements in the engineering physics curriculum will most sensibly be adjusted to take advantage of local features, certain general aims seem reasonable. The outline of classical and modern physics should be taught with attention to breadth of treatment and understanding rather than narrow specialization. In selected courses in basic engineering some of the realistic views as well as the techniques of engineers can be studied. A manipulative familiarity with mathematics and chemistry is necessary. This may prove difficult to acquire, unless suitable intermediate courses in these fields are offered—courses which do not put premature emphasis on specialization and mathematical rigor. The laboratory work in physics should at an early stage begin to emphasize methods of *approach* to problems, as well as the intelligent synthesis of various techniques of physics and other scientific disciplines. The development of self reliance and mental "handyness" cannot be deferred to graduate school, since most students in this curriculum may never, or not immediately, proceed beyond the bachelor degree. The curriculum, finally, should involve as thorough an education as possible in cultural subjects. The argument that time is more urgently required for professional training does not seem entirely valid—a breadth of vision extending beyond technical details should be part of the stock of an engineering physics graduate.

To implement these aims, should not the physics courses (at least) in the curriculum be studied very carefully by the staff, to be sure they mesh into an intelligent pattern? These courses should not be simply the preferred offerings of specialists, oblivious of other

subjects, or a very real waste of time may result. So far as can be arranged, of course, this attempt at integration should continue with the required courses in other departments and fields.

Should not an equally important responsibility of the physics staff be to instill into students a respect for the work of men in other allied fields? Instructors should be sufficiently broad-minded and well-informed to be able to explain *why* the engineer (or mathematician, chemist, biologist—or physicist, for that matter) attacks problems as he does. Friction and strong feelings arise in the college faculty as elsewhere, but it is not for the student's good to foster a consequent feeling of superiority toward those in other technical fields. As a plain matter of fact, he would fall as short in attempting to fulfill their proper duties as they would in his.

In amplification of an earlier remark, should not the laboratory work in the curriculum be especially carefully planned? Some important experience of this type can be gained in engineering and chemistry courses, and the physics work should take fullest advantage of this. In the physics laboratories, some "push button" experiments should be included, for the student must acquire familiarity with elaborate precision apparatus which works as a matter of course and not of chance. Some of the classical experiments may be included for pedagogical reasons. Mainly, however, the work should be of practical purport, having something of "project" nature, and stressing combinations of methods. Certain standard tools and procedures must be studied, as far as possible by *using* them—such things as shop skills, glass working, circuit assembly, vacuum techniques, spectroscopy, photography, pyrometry; the basic electronic devices in simple uses —thermionic, photocell, and cathode ray tubes; standard optical equipment and systems; a nodding acquaintance with a wide variety of standard electrical measuring instruments.

Always the stress should be on acquaintance with many tools before detailed specialization in a few. The use of instruments and techniques should precede (though not preclude) the detailed study of their theory. Building on this wide acquaintance, the student may start learning to combine, correlate, or substitute methods to achieve a desired result.

Throughout both laboratory and class work, emphasis should fall on the inspection and analysis of data, even though the first steps are stumbling ones. Here, as in the experimental procedures, general understanding and appreciation of the difficulties involved is a more important aim than technical proficiency in the classical theory of errors. An early introduction to graphical and numerical analysis is a necessary part of such training.

To counteract the risk that such broad, and necessarily incomplete, training may produce only a Jack-of-all-trades, a rather exacting senior thesis may be assigned. The topic should be carefully selected. For example, a theoretical investigation, a survey paper, or assistance in the research of a staff member may not be most useful to an engineering physics student. The design, construction, and calibration of some simple apparatus or instrument may be much more helpful to him, particularly if it involves several different principles (perhaps from mechanics and optics, or elec-

tricity and optics), and if it is completed in time to allow the student to put it to use.

May not the inclusion of such suggested methods in the curriculum turn out a desirable graduate—reasonably familiar with a variety of technical subjects, techniques, and instruments; indoctrinated toward the application of these in new situations; with, in the senior thesis, the beginning of personal research to help put him at ease with other researchers; and with an intelligent respect for the opinions, procedures, and attainments of other technical workers?

New Members

Buck, Nelson L., Professor of Mechanical Engineering, Washington and Jefferson College, Washington, Pa. W. D. Stevenson, W. C. Johnson.

Byrne, William E., Professor of Mathematics, Virginia Military Institute, Lexington, Va. C. E. Kilbourne, S. W. Anderson.

Carragan, George H., Professor and Acting Head, Dept. Physics, Rensselaer Polytechnic Institute, Troy, N. Y. K. H. Moore, J. G. Fairfield.

Carter, William J., Assistant Professor of Mechanical Engineering, University of Texas, Austin, Texas. V. L. Doughtie, B. E. Short.

Holian, Austin J., Instructor in Electrical Engineering, University of Dayton, Dayton, Ohio. L. H. Rose, A. R. Weber.

Jenness, Roger R., Instructor in Electrical Engineering, Northwestern University, Evanston, Ill. E. W. Kimbark, R. W. Jones.

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Reynolds, James I., Assistant Professor of Mechanical Engineering, West Virginia University, Morgantown, W. Va. W. H. Baker, H. M. Cather.

Rose, Robert L., Instructor in Mechanical Engineering, Illinois Institute of Technology, Chicago, Ill. S. E. Winston, L. E. Grinter.

Sheehan, William M., Vice President, General Steel Castings Corp., Eddystone, Pa. L. J. Fletcher, A. R. Stevenson.

Thomen, Jacobo A., Professor, University of Santo Domingo, Socorro Sanchez 17, Ciudad Trujillo, Dominican Rep., W. I. L. W. Clark, Frederick Abbuhl.

Waibler, Paul J., Instructor in Mechanical Engineering, Yale University, New Haven, Conn. C. W. Phelps, F. R. E. Crossley.

Willey, Calvin M., Instructor in Mechanical Engineering, Carnegie Institute of Technology, Pittsburgh, Pa. W. S. McKee, Leroy Olsen.

37 new members this year.

Sections and Branches

Following is a list of the activities of the **Michigan State College Branch** of the S.P.E.E. for the school year 1944–45. The Branch opened business in the Fall with the following officers:

L. C. Price, Chairman
E. G. McKibben, Vice Chairman
C. A. Miller, Secretary
D. D. McGrady, Treasurer

The above, with C. L. Allen, past Chairman, made up the Executive Committee.

We have held two general meetings, one on May 29th. The subject was "What should an Engineering student get from his laboratory courses?" Prof. L. C. Price, Chairman of the local Branch, opened the meeting. He then introduced Prof. J. M. Campbell, Chairman of the Program Committee, who conducted the remainder of the program.

Dean H. B. Dirks of the School of Engineering was asked to make a few remarks and he cited the importance of laboratory work in Land Grant Colleges.

The following men were then introduced: E. G. McKibben, head of the department of Agricultural Engineering; D. D. McGrady, Assistant Professor of Chemical and Metallurgical Engineering; C. M. Cade, Professor of Civil Engineering; O. W. Fairbanks, Associate Professor of Engineering Drawing; B. K. Osborn, Associate Professor of Electrical Engineering; S. D. Gralak, Assistant Professor of Mechanical Engineering. All of these men gave ten minute talks with discussions following.

Our second general meeting was held on the evening of June 4th. This was a dinner meeting and the wives were welcomed. The speaker of the evening was Charles H. Hayden, Circuit Judge of Lansing. His talk was on the welfare of the younger generation. He illustrated his talk with every day happenings in court.

Our Branch sponsored six radio talks. Prof. L. C. Price led off with the topic of General Engineering Education. The other talks were given by a member of each of the engineering departments.

C. A. MILLER,
Secretary.

College Notes

The Ohio State University.—Five-year curricula, replacing the present four-year programs, in all degree-granting departments of the College of Engineering will become effective with the autumn quarter.

The plan, which will bring more of the so-called "cultural" courses into the engineering curricula, will become effective with the new freshman class. Present students, returning students whose work was interrupted by the war or for other cause, and students transferring here from other colleges will be permitted to choose between the four- and five-year curricula, this option continuing until two years after the war.

One of the engineering departments, architecture, has been requiring five years for graduation since 1929.

To meet the problem of adequate recognition of the additional time spent and competence attained by the student completing the five-year curriculum, Ohio State has provided for a differentiation on the basis of academic standards. Men having superior academic averages at the end of the third year may enter a special program which, if pursued successfully, will lead to a master's degree as well as the bachelor's at the end of five years. Those with averages below the specified requirement will receive the bachelor's degree only at the end of the five years, but they will have had the benefit of the humanistic as well as the regular engineering subjects.

The new Ohio State program will call for 84 quarter hours of fundamental courses; 51 hours of "broadening" studies; 19 hours of required general work, such as military science, physical education, and survey courses; 120 to 126 hours of departmental work—a total of 274 to 280 hours!

The 51 hours of "broadening" studies may come from such fields as economics, political science, sociology, economic geography, psychology, business organization, international studies, history, and others.

The plan adopted is patterned to meet the needs outlined by the Society for the Promotion of Engineering Education, in a report by the society's Committee on Engineering Education after the War.

Necrology

HOMER HEATH NUGENT, Head of the English Department, Rensselaer Polytechnic Institute, died suddenly May 28, 1945 at his home in Troy, New York.

He was born October 27, 1893 in Waterbury, Connecticut. A graduate of Harvard University in 1916, Mr. Nugent was appointed Assistant in English at Rensselaer Polytechnic Institute in 1916–1917. From September 1917 to March 1919 he was in military service. After serving as Assistant Representative of the United States Civil Service at Camp Devens, Mr. Nugent was appointed instructor in English at Rensselaer from 1919 to 1923, when he was made an Assistant professor of English. He acquired an M.A. degree in English at Columbia University in 1922, and he pursued further graduate work at Columbia in 1927–28, serving in the same year as instructor in English at Washington Square College. In 1928 Mr. Nugent was appointed Professor of Rhetoric at Rensselaer Polytechnic Institute, and in 1940 he was made Head of the English Department.

Besides being an accomplished after dinner speaker he contributed short stories and plays to various periodicals, edited *A Book of Exposition*, and was co-author of *How to Write*. A member of the Modern Language Association, College English Association, and various civic organizations, Mr. Nugent was for years particularly active in the Society for the Promotion of Engineering Education. Through papers and the chairmanship of the English Division he has helped shape the policies of English education in Engineering schools. When he died he was active on a special committee which sponsored the new Humanities Division.

Physics Column

Having undertaken to prepare a monthly Physics Column for THE JOURNAL, your chairman is confronted with the embarassing necessity of preparing the second issue of the column before the first has been distributed to the readers. In the first issue of the column it was declared that subsequent columns would be limited to news submitted voluntarily by the readers. It is hoped that before the time has arrived to prepare the third column news will be flowing in steadily on activities, findings, and trends in physics departments concerned with engineering education. Suggestions on types of news which will be of mutual value to physics departments are contained in the September issue of this column. Send your contributions without delay—and continue to send them—to the secretary of the Division, C. E. Bennett, University of Maine, Orono, Maine, or to the Chairman of the Division, J. G. Potter, A. & M. College of Texas, College Station, Texas.

A few items which have found their way to your chairman are presented at this time.

The advent of the atomic bomb having verified for the public that World War II was "a physicists' war," physics departments are endeavoring to prepare for unprecedented student loads. Although steps are being considered for the restriction of enrollments to students genuinely competent to pursue work in physics, grave anxiety is being expressed over the obtaining of adequate teaching personnel. Many of the physicists who left educational institutions to assist industry in the war program have been found by industry to be such an asset that they will be induced to remain there permanently. In the absence of a crop of younger physicists to replace these physicists and others retiring from academic departments for different reasons, there is scant hope of restoring physics department strength even to pre-war levels.

The physics department of Illinois Institute of Technology is progressing in development as a center for electron microscopy. In addition to the versatile R C A Type B magnetic electron microscope which has been in operation at the Institute for a number of years and has been extensively used recently to contribute in the war research program in the Chicago area, the physics department has lately put into operation an R C A Console Model electron microscope. A similar instrument is also in use in the Research Foundation of the Institute. Plans are underway by the physics department to add an R C A Micro-Analyser to the laboratory.

I. Walerstein, of Purdue University, reports considerable interest in a non-credit one semester hour lecture course he has given the past few semesters. The course has been devoted to tracing, often historically, the development of various selected fields of classical and modern physics. The course has attracted as many as twenty upperclassmen, the majority being engineer-

ing students and the remainder physics majors. Practically all members attended faithfully throughout the semester.

J. H. Howey, of Georgia School of Technology, in expressing the desire to see in the Physics Column descriptions of experiences teachers have had in making beginning college physics more interesting, offers one example. He calls attention to the opportunity to utilize more of the existing commercial equipment. To quote, "We have used a commercial recording and controlling potentiometer in connection with our study of the potentiometer. The self-balancing feature of the instrument seems to awaken considerable interest and I believe that money for this equipment was wisely spent. We plan to continue using it in our laboratory as an exhibit to follow the student's experiment in which he uses the conventional slide wire potentiometer. We expect that most departments have discovered things like this which they would be glad to recommend for use in engineering courses. Such things might be worth mentioning in informal letters in the column."

In the readjustment of academic schedules occasioned by the relaxation of the national emergency, there has been brought to the attention of your chairman the cases of several institutions where the time allotted to required physics courses in engineering curricula has been increased by a fraction of a semester hour. Information concerning any larger trends of this nature will be received with great interest in this column.

JAMES G. POTTER,
Chairman, Division of Physics

Teaching the Facts of Professional Engineering Life

By E. A. HOLBROOK

Dean, Schools of Engineering and Mines, University of Pittsburgh

In the so-called Victorian Era, parents were so modest that they hesitated to tell their children the facts of life. Possibly a like modesty restrains present day engineering deans and professors from informing their undergraduates about two paramount facts relating to the young engineers' future professional life. These facts are as follows:

1. Under the Wagner National Labor Relations Act of 1935, now the law of this country, and as interpreted by the National Labor Relations Board, engineers in many capacities and levels of attainment face a lifetime of labor union affiliation or membership. This law is not a temporary war regulation, and it remains in force until and if changed by Congress.

2. The laws of forty-six states at present require certification and registration of engineers before they may practice the profession of engineering in the particular state.

It appears that these two facts are closely related; that they are permanent conditions that will vitally affect this and every future generation of engineers, and that every graduate should be informed on how and where they will help or hinder him in his quest for professional success. If we of the colleges are concerned with preparing men for life, knowledge of these two realities may be of more technical value to them than the details of any single engineering subject, and of more cultural value than any particular nontechnical elective of the undergraduate course.

We who are engaged in teaching embryo engineers have been strangely silent and even ignorant of the great forces at work which are making unionism and professionalism part and parcel of the working life of every engineering graduate. Recently I heard competent engineering teachers and even prominent engineering graduates belittle the dangers of unionism by statements to the effect that it did no harm for a young engineer to join a union, that when he ceased to be an apprentice, the engineer would be beyond the labor union stage, and that the experience would have been good for him. In the same vein many engineering professors have told me loftily that they were against state registration of engineers, that they were not registered themselves and did not intend to register. Let us look more deeply into the facts as they face us in 1945 and in every future year. Let us forget our boasted independence of 1925 when we thought we were able to face professional life under our own steam, and without brakes or blockades.

(1) What are you telling the engineering student about the National Labor Relations Act? Do you tell him that, in all industrial positions he may accept after graduation, he may be

compelled to join a union and thereby lose many of the ethical freedoms that you have taught him were his right by reason of his training and education? Do you tell him that even though he be able, industrious and ambitious, his progress in many industrial corporations will be governed by the seniority rules of the union? Do you tell him that the Labor Board's definition of "professional" and "technical" may not coincide with yours and his, and that he may have to continue in the union even though he be doing work of a high scientific and technical nature? Today, legalized unionism goes far above the apprentice stage, and even full membership in a National society will not protect an engineer from union control.* Do you tell him how he can take steps to get into the "appropriate unit" in his collective bargaining agency, and how he can be protected from discrimination on the part of employers if he exercises his right to enter a union or a collective bargaining unit? Do you tell him that his "appropriate" unit may be decided for him and that, as a graduate engineer, he may find himself included in the bargaining group which includes engineers, laboratory helpers, clerks, and janitors? Do you tell him that if he tries to remain an independent technical worker, he may no longer have an opportunity for advancement in American industry and, indeed, may be denied employment? Certainly, if he tries to remain individualistic, there is little protection from discrimination either from the company or from the "appropriate bargaining unit."

*Note: In a recent case, a consulting chemical engineer was forced to join a union before he could enter the company plant to undertake professional examination.

It is noteworthy that the National Labor Relations Board is admittedly biased in favor of the organized worker, and that their findings are not subject to a court review. It is true that an engineering graduate who has entered a bargaining unit, either with his professional co-workers, or in some heterogeneous unit, may hereby improve his monthly salary pay check; whether by this action he improves his professional future and his professional ideals is quite another question. How are you going to advise your graduates?

That the union question is not some passing attack on technical men or a question of interest only to the low grade underpaid recent engineering graduate, I brief the following from the Chicago Daily Tribune, January 20, 1944:

"TECHNICAL EXPERTS STRIKE IN FORD PLANTS"

The article details that 650 technical men at Ford's Rouge plant went on strike. The scientists included engineers, chemists, metallurgists, and physicists who test metals and supervise the treatment and alloying of the metals used by the company. The demand of the union was that all research work be done by union members with wage increases and a pay demand for their lunch period! How the research ideals and professional loyalty we engineering teachers have been trying to instill into our students for generations can be synchronized with a clock punching, ambition excluding group of scientific and engineering introverts, is beyond me. How are you going to advise your students for this new world?

To engineering teachers interested in knowing what your graduates will face in industry, I advise that you read an

excellent new book on the subject called *Technologists' Stake in the Wagner Act* published in 1944 by the American Association of Engineers, 8 South Michigan Avenue, Chicago 3, Illinois.

(2) What are you advising your students about becoming registered professional engineers?

Some twenty years ago I took part in a movement to have a recently enacted State of Pennsylvania professional engineers registration act declared unconstitutional. Many of the engineering greats and near-greats of the time applauded loudly. Hardly had the excitement died down when out of somewhere came a great new force putting through the Legislature a new engineers' licensing act which did stand the test of courts. I investigated and found the backers of the act were the rank and file of the engineers of the state. They were the great average engineering graduates of your school and mine. They were employed by cities and state, by small industrial concerns, and also included men who were engaged in the individual practice of our profession. Not a single engineering professor had helped the movement, most of the National engineering societies had ignored it, and many industrial concerns employing engineering graduates were passive or even opposed so far as their engineering staff was concerned. All sorts of reasons we put forth against this legal recognition of engineers, ranging from a fanciful opposition to regimentation, to the plea that an engineer was not, after all, a professional man in the same sense as a lawyer or a doctor, but only a glorified mechanic.

Then and there I decided that the professional engineer could not just stand still and tell the changing world to keep its hand off. We older men have seen the improvement in the practice and ethics of the medical and legal profession which had come about through their registration and licensing acts. If we, as engineers, are ever to obtain public recognition, and respect, and influence, it must be through state accreditment and licensing. If our ethics are ever to have binding power, it must come from a common legalized unity.

I ask that the engineering teachers in our colleges inform themselves and their students that a graduate engineer may be out of luck if he goes to a foreign country to work without legal professional standing. Most foreign countries, including Canada, have a rigid and advanced system governing licensing of engineers. Indeed, Canada and Canadian engineers have accepted wholeheartedly in theory and practice the examination, registration, and induction of men into the circle of professional engineers. Tell the students what standing engineers registered or not registered in your state have when they engage in work in another state.

It is true in some of the forty-six states now having registration and laws governing the practice of engineering, there are poor and weak laws with many loopholes, and some states have laws providing for the registration of only those engineers who are engaged in a special kind of work. On the other hand, New York and Ohio have engineers registration and licensing laws that ought to be a source of pride to every engineer in those states. Only this month, Pennsylvania has entered the company of these two states by passing a revised registration and licensing law requiring written examination and other qualifications to be met by every person who announces himself as an engineer. The registration

acts of the so-called model law of these three states agree closely and provide fully for placing engineering on a professional basis comparable with medicine or law. In particular, these model laws bring out the significant fact that the practice of engineering is an individual attainment, and that so-called engineering firms or corporations not made up of individually registered professional engineers may not be legally qualified to undertake engineering there.

Certainly, you would not send your son to a medical or law school which was not staffed by registered doctors or lawyers. In the same way, I look forward to the time when the public will expect the professors in our engineering schools to have not only academic titles, but also that of a registered professional engineer. I hope every engineering school will urge its professors to secure a state certificate of registration.

An interesting point for engineering educators to consider is that the laws of the above states make provision for the classification of the young graduate as an "Engineer in Training." Other states, as Iowa, Georgia, Minnesota and Missouri, have or shortly will have the same plan in force. Tell your seniors that if they are going to work in these important industrial states, they should immediately take the state written examination for the status of "Engineer in Training." This examination covers the theoretical engineering subjects the student was supposed to learn under you. If passed, it exempts him, when he applies for his professional license a few years later, from having to take a written examination on those subjects, in which he may be rusty. Posibly in the near future, the ability of your graduate to pass these "Engineer in Training" examinations may be a fair measure of the kind of training you have given him.

To engineering teachers who have neglected or are not qualified to obtain a professional license, let me say that it is now illegal in the three states mentioned to call yourself or to hold yourself by any announcement to be qualified as an engineer, or to engage in engineering work of a professional nature. In a court case, engineering work by a nonregistered engineer would have no legal standing.

All of this you may not like, but today your graduates go out from college headed either into professional engineering or into a lifetime of trade unions. We are all together headed toward a unified profession or toward a skilled craftsmanship. We can't continue to stand in the eddy; it is our duty to so advise our young men.

Personally, it is distasteful to think of the men we are training technically for leaders, ethically for high responsibility, and socially for an individual life, grabbing at the easy way of making a living through collective bargaining, mass leadership and rules that stress seniority rather than ability. Let us rather meet our responsibility as engineering teachers by helping in the efforts of our practicing colleagues to pass and enforce laws in our respective states governing who may practice engineering and prevent the incompetent and unworthy from lowering our estate in the eyes of the public and of the government services. In particular, let us back the efforts of our state Boards of Engineering Examiners in their efforts to produce a profession of decent professional and ethical standards. Be an example to your students by being yourself a registered engineer.

Perhaps most important of all, acquaint your graduates with the provisions now in effect in some states, and soon to be in others, that by becoming "Engineer in Training" they put themselves in the line that leads away from trade unionism toward the goal they must reach—that of a registered professional engineer.

Admittedly at present, there is no clear-cut decision of the Labor Relations Board that would definitely exclude an "Engineer in Training" or a registered professional engineer from being required under some circumstances to join a union. There is, however, every reason to hope that when we become legally established and recognized as a profession, we may expect the same legal treatment as accorded doctors and lawyers, if we are engaged in an actual professional capacity.

There are many definitions of an engineer that you may give your students; the one I like best and offer for your consideration is that "An engineer is a man who has been legally qualified to practice the profession by the laws of his state." With this as a goal, all petty definitions as to kind of work or as to duties and responsibilities, and all admonitions on how the engineering graduate should conduct himself, are trite. A competent graduate will become truly a professional engineer if we point out this way to him.

S.P.E.E. Ambassador of Good Will

By S. S. STEINBERG

USA I

Union Sudamericana de Asociaciones de Ingenieros
DIRECTORIO

Montevideo, September 3, 1945

Engineer S. S. Steinberg
Dean, College of Engineering
University of Maryland
City

Dear Sir:

I take pleasure in informing you that the Board of Directors of the Union Sudamericana de Asociaciones de Ingenieros (South American Union of Engineering Associations) decided at its last meeting, taking into consideration the qualities with which you are gifted, to appoint you its Special Permanent Representative to the Engineering Associations of the United States of America with the purpose of establishing a cultural and technical interchange in its many phases.

In addition, the Board of Directors, in its above-mentioned meeting, decided to specially recommend to your attention the advisability of taking any steps you deem necessary to enlist the cooperation and technical support of the public institutions in your country for the Pan American Congress of Engineering to be held in Buenos Aires next year under the auspices of the Union Sudamericana de Asociaciones de Ingenieros.

I am sure that my distinguished colleague will honor us by accepting the responsibility which the Board of Directors of the U.S.A.I. has conferred upon you and that your help in this regard will be most valuable.

I take this opportunity to present my very cordial greetings.

(signed) JOSÉ L. BUZZETTI,
President.

(Translation)